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Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development

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**IMPLICATIONS OF NATIONAL INNOVATION SYSTEMS FOR
DEVELOPING COUNTRIES
--MANAGING CHANGE AND COMPLEXITY IN ECONOMIC
DEVELOPMENT****

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ABSTRACT

This paper develops implications of National Innovation Systems (NIS) from the perspective of developing countries. A review of the development of NIS in the OECD context reveals that the notion of national innovation systems is a synthesis made at the national and other societal levels, of the insights about technological innovation and institutional change. Its strong policy orientation came from the need to manage change and complexity for economic growth and development. It should be adapted as one of the most relevant policy instruments for knowledge based development in developing countries. The paper identifies gaps which may impede possible applications of the innovative policy approach of NIS, mainly in the preparation of people for change, and in the development of a knowledge basis for the learning intensive policy approach of NIS. The paper also illustrates how to make efforts to narrow the gaps.

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1. INTRODUCTION

This paper concerns possible applications of national innovation systems (NIS) approach into the circumstances of developing economies. ‘Developing economies’ is a vague and disputable term, for every economy is in development, including those that are advanced economies. In addition, great diversity and disparities exist in the group of developing economies so categorized in World Bank publications. Nevertheless, as a group, the developing economies do share some commonalties specifically associated with their backward situations in economic development, such as low level of quality of life and systematically different features in institutions (Sen 1991). They are, up to present, commonly attempting to catch up as well. It is special problems, rather than development in general, that the paper takes into consideration as of economic development in developing economies. This paper attempts to interpret where there are gaps for possible applications of NIS there, and how the gaps can be alleviated.

The notion of national innovation systems is developed relatively recently from the backgrounds of advanced economies. A succinct definition can be found in the recently published OECD report on NIS project (OECD 1999b: 24) as follows.

National Innovation systems are defined as the “...set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies. (Metrcalfe 1995)

From this perspective, the innovative performance of an economy depends not only on how the individual institutions (e.g. firms, research institutes, universities) perform in isolation, but on “how they interact with each other as elements of collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal frameworks)”. (Smith 1996)

The Science and Technology Policy Committee of OECD (OECD 1999b: 3), and many participating scholars and policy makers of OECD countries believe that the systemic approach opened by NIS has profound policy implications which would bring OECD countries into a new generation of science, technology and innovation policy making. An enthusiasm is also growing in researchers from developing countries. For example, there are sub-sessions in the DRUID 1999 Summer Conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, a number of good work have been emerging. But in general study on developing countries has not fully started, while difficulties and confusions appear. What is the NIS approach all about? What are the policy implications of NIS for developing countries? We

approach these questions first of all by a quick review of the achievements reported in OECD (1999b) under three distinctive but related titles: policy themes, analytic tools, and policy institutions.

Firstly with respect to policy themes, a number of areas are highlighted as important under the NIS perspective, which were before either less emphasized, or separately studied but not dealt with as important systems components collectively responsible for the innovation performance of an economy. They are (OECD 1999b: various chapters): a) innovative firms--the internal competence of the firm in bringing in technological and organizational change and the network patterns and conditions of the firm in which it is operating; b) clusters--the identification of industrial clusters (namely a number of firms, universities and other research institutes, bridging institutions and customers, which are linked in a production chain creating added value); and the ways of interactions among different parts of a cluster; and c) characteristics of national innovation systems--the institutional profile of national innovation systems; linkages within and among innovation systems; the specialization patterns of national innovation systems in scientific basis, technological innovation, and international trade; and the patterns of these systems in development and growth, notably productivity growth.

Apparently policy focus of OECD countries is re-shaping. Higher attention is given to address areas such as functional mismatches, incentive conflicts, and barriers, weaknesses and asymmetries existing in the system that reduce the efficiency in producing, disseminating, and using knowledge for innovation. 'Innovation infrastructure' is taken as one of the most important attributes of the systems which is acknowledged critical for long term innovative opportunities (OECD 1999b: 63-68). In short, 'systems failure' and weaknesses, rather than merely market failure--the latter was the rationale for policy measures under conventional view of technological change--provides guidance for policy making.

Secondly, analytical tools are considerably renewed (OECD 1999b: various chapters), developed first of all for the need for exploring the various themes mentioned. Institutional mapping and functional analysis, cluster analysis (also OECD 1999c), labor mobility analysis, the analysis of embodied knowledge flows, and policy practice analysis are among the most important developments. Combining quantitative and qualitative methods together to accommodate special analytic requirements of the systems approach is one of the prominent characters, provided that institutional factors are less quantifiable. Impressive is the intensity of data use and the sophistication of data processing, such as the adoption of input-output table upon which clusters are identified, and 'embodied' or 'indirect' R&D input calculated. Certainly these analytical methods are not only useful for NIS survey, but also will be, and have been, supportive to policy implementation and policy evaluation following the NIS approach.

Thirdly and very interestingly, the OECD NIS project has included a survey of policy institutions (OECD 1999b: 38). It has identified that the policy institutions of OECD countries are significantly country-specific and path-dependent (OECD 1999b: 68), typical features which have been discovered from studies on technological change and institutional evolution. It is recognized that policy priorities and policy means differ among OECD countries, influenced by size and level of development, industrial, scientific, and technological specialization, institutional structure, and domestic patterns of knowledge interaction. Policy hence is seen as outcomes from the interaction between country specific policy institutions and country specific innovation systems. In response to the learning-intensive policy process of NIS as such, a wave is prevailing in the establishment of new policy research institutes in a number of OECD countries (see e.g. OECD 1999b: 71-76; 1998a). They investigate, study, and disseminate relevant information systematically and timely, to improve a knowledge basis for the policy process in which broad participation is involved by academics, government agents, and business companies

Put together policy themes, analytical tools, and policy institutions as reviewed, the recent progress in OECD countries is substantial. Science and technology policy tends to be managed in OECD countries more effectively with the guidance of a systems' perspective, and more consciously in combining short and long term innovation potentials. The separation problem of science and technology policy from economic policy and economic performance seems to be mitigated there, although its full consequence has not been uncovered yet.

We admire the progress, and believe that to manage change and complexity more efficiently in developing countries is at least no less critical than in OECD countries. However, as a firm can not innovate in isolation, and a new product can not be transferred to somewhere else without adaptation and complementary inputs, the policy innovation brought about by the NIS approach can not be understood and applied appropriately without checking the contexts in which the idea is intrigued and developed on the one hand, and in which it is expected to be an intellectual instrument for science and technology policy for economic development, on the other. This paper reports a primitive outcome from an effort of this kind, it is taken by the author, a student who comes from the non-OECD South, and works for the South on science and technology policy.

Section 2 explores the background from which the idea of NIS emerged. The intellectual sources are reviewed which were from the tradition of technological innovation economics among others. The challenges are discussed which the OECD societies perceived from international competition and from the advances of new technologies since the 1980s. In response to the challenges, the concept of NIS developed out of the research tradition, in order to improve policy capacity for national economic performance. The NIS approach represents a

policy innovation, and now a social-wide shift of attitude towards the acceptance of change is widespread in OECD countries. The evolutionary theoretical departure in policy process by the NIS approach is elaborated.

Section 3 reviews methodological specifics involved in NIS studies, with a special attention given to possible confusions encountered by the researchers who were not experienced in studying dynamic changes. Methods used for a NIS study are specific in that micro-foundations constantly constitute a large part of the work, which are assumed containing reasons and rules for explaining changes observed at aggregate systems level. Besides, each survey has to be in principle specifically designed. The purpose is to be especially set up, the analytical framework to be developed and the analytical boundaries to be delineated. There is no survey plan immediately and universally applicable. This methodological specifics of NIS approach is determined by the underpinning dynamic complex systems conception of NIS, uniquely distinctive from conventional approaches.

Section 4 discusses some particular characteristics of national innovation systems in developing countries. Although nobody would state literally that science and technology play no role, and change and technological innovation has no relation with economic development in developing countries, the experiences with science and technology have been very diverse there. Presently, just in the opposite of OECD countries where the moods of politicians and academics are moving towards change, the trends in developing countries is towards balance. A quick review indicates that there is an urgent need for theoretical innovation of development economics, and that there are progresses emerging in this direction. The recent work by Fei and Ranis in their 'an evolutionary framework' of economic development represents one of the progresses, can be a theoretical foundation, for NIS survey being communicated with development economists. Drawing upon both the Fei and Rains' evolutionary framework of economic development, and the OECD framework of national innovation systems, we develop some characteristics of NIS in developing countries.

Section 5 illustrates NIS survey themes. They are in correspondence to that in the OECD NIS project, but put in the context of developing countries. A review of the widely accepted technology life cycle theory finds that late entry of an industrial follower can not be satisfactorily explained. Institutions supporting for cross-boarder knowledge flows deserve a special attention. Firms are the major actors of technological innovation. But with inexperienced latecomer firms in developing countries, research focus needs to be given to the accumulation process of firm-specific knowledge. This is a process that should transform an inexperienced imitative latecomer firm into an experienced innovative firm, if it learns extraordinarily intensively with imported technology. This section goes on to allude specific patterns of innovation systems, based on a very brief comparison between South Korea and Taiwan

Province of China (thereafter simply Taiwan): interaction with international knowledge inflows; network development; the role of FDI in cluster promotion; selected strengths in technology; and the institutional patterns of technological infrastructure. It shows that the two systems of South Korea and Taiwan, though rather comparable in macroeconomic terms, are quite different in institutional structures and development paths, to which we had been rather blind. This section also interprets the adaptive policy process of the NIS approach in the context of developing countries. It contends that a shift of the way of policy making into an adaptive learning process is decisive. Extraordinarily intensive policy learning is necessary if policies are to play a role in the strategic management of historical transition of their innovation systems in developing countries.

2. NIS IN THE CONTEXT OF OECD COUNTRIES: INTELLECTUAL SOURCES AND THE NEED FOR MANAGING CHANGE AND COMPLEXITY

We begin our exercise with a quick journey to the developed world where the idea of NIS emerged and is becoming socially accepted. We would like to learn the intellectual sources that not only support the notion of NIS, but also serve a reasonably well-developed knowledge basis for the NIS approach operational once it comes. We are also interested in policy concerns behind the development of the idea of NIS, which, if any, might give an allusion to why NIS is linked with policy purpose and how. The two themes, i.e., the intellectual sources of NIS and the policy orientation of NIS are organized under the first and second parts of the section, respectively, with the headings: *Two Lines of Modeling of Economic Phenomena and the Concept of NIS*, and *Emerging Social Needs and the Policy Orientation of NIS*.

Although policy practice is often a matter different from policy theory, one can not appropriately understand NIS without consulting its theoretical basis, which is the evolutionary view of technological innovation and economic development, from the tradition of technological innovation economics among others. In this perspective, research focus is put on change and reasons for change. In response to the challenges raised from international competition and from new technologies, the concept of NIS emerged out of the research tradition, in order to improve policy capacity for national economic performance. With the development of NIS, policy making and the relationship of policy with publics are in change. As mentioned in the introduction section, intensive knowledge input, specifically tailored policies in addressing country-specific and problem-specific issues, adaptiveness and flexibility to feedbacks, are among the changes spreading OECD countries. A social-wide shift of attitude towards the acceptance of change and innovation is taking place. The evolutionary theoretical departure in policy process of the NIS approach is elaborated in the final part, titled *An Evolutionary Theoretical Departure of NIS and its Enlightenment*.

The journey reported in this section is made for readers from the South. We believe, as we ourselves learned enormously from this, that it is necessary. It helps to recognize where the gaps are and to fill the gaps if we wish the innovative NIS approach of policy to be introduced into the South. One of the gaps is in the qualitatively or orderly lower levels of innovative ability which developing countries run incomparable with their advanced counterparts. A tentative identification and explanation on this is reported in Section 4. Another gap is in the accumulation of knowledge necessary for a productive survey on NIS, provided that researchers from developing countries were not much involved in the tradition of technological innovation

studies. We try to interpret, which is reported in Section 5, several surveying themes included in the OECD NIS project, into the context of industrial latecomers, for calling the attention of local researchers to develop relevant knowledge basis for the application. The journey to the OECD origin of the NIS also highlights that methods used for NIS survey is rather different from conventional approaches, because the way it conceptualizes the subject of innovation systems is novel. We are instructed to devote an effort on the methodological specifics of NIS study, reported in Section 3. In short, this section gives indications why we do that which are presented in following sections. Those who are familiar with the development in technological innovation studies and with the NIS approach may escape this section entirely.

Two Lines of Modeling of Economic Phenomena and the Concept of NIS

Theories are conceptual models of the world made by observers. Theories work as mediator instruments assisting our cognitive capacity development to comprehend the world in observation; distinctive theories devise differentiated focuses. Having the division of intellectual labour greatly developed, theories are generated in the developed world propitiously, they debate, compete, and adapt to each other. Generally speaking, there are two lines of theories with respect to economic phenomena, the neo-classic view, and the evolutionary view. They serve as focusing devices not only for observations, but also for policy making for, in our focus, science and technology, in order to promote technological innovation and improve economic growth and development.¹

The neo-classic view conceptualizes, in its very core, firms and consumers independent or ‘atomistic’ economic agents. They are fully informed about prices at the market place, and produce, sell, and buy in the way in which they maximize the utility of the resource they are endowed. The market meanwhile achieves the state of perfectly competitive equilibrium that also maximizes the welfare of the society as a whole. Where an ideal state of perfectly competitive equilibrium does not achieve, the deviation is called market failure, additional action to correct it is then necessary. This serves the rationale for policy intervention in this line of conception. Examples are environmental policy which deals with negative externalities discharged from individual producers that deteriorate environmental quality, and anti-trust policy which addresses the distortion of the market where only one or few sellers dominate the market of a certain product or service. Directly related to science and technology policy is the

¹ The following paragraphs are only for introductory purpose to bring in the discussions below. It is impossible here to systematically describe the two lines of theoretical perspectives. Metcalfe (1995) provides a thorough review on this topic, also Metcalfe (1998), Metcalfe and Georghiou (1998), Lipsey and Carlaw (1998). All of them focus on policy implications of these views.

notion of public goods of knowledge. A piece of knowledge can be used many times by many users with little decrease in its value, that gives inadequate incentives to private firms to invest in knowledge generation. Patent laws, subsidies to private (company) R&D, and public investment in basic science, are therefore solutions for a remedy.

One of the major shortcomings of this line of rationale rests on the assumption of symmetric firms, homogenous technology and knowledge. Structural and institutional differences are in the absence of interest. Policy goals and measures are postulated either too general, or ad hoc. It is weak in linking science and technology with economic development of long run, for the theoretical focuses are intrinsically insensible to change and the mechanisms of change. With respect to technological change, the notion of information asymmetries is developed in this line to explain why difficulties occur, which however is too feeble to increase our knowledge or to improve policy making. Suppose there is a potential innovation. Although the innovative entrepreneur has a rough idea though as what the innovation could be, though, his user and supplier do not. Knowledge is in such case distributed unevenly, which is called information asymmetries. Moral hazards thereby occur which prevent related agents from acting in the maximizing way, and the market functions deviated from perfect allocation of resources for the innovation. Such an explanation does not grasp the nature of technological innovation at all.

As has been observed plentifully from studies on technological innovation, a potential market for an innovation, if it might eventually emerge, will be created only through complicated interactions between its producer, supplier, user, and competitor. Each partner may change the route in which he takes action throughout the process, in response to gradually revealed information about the technology and its market. What will come out from a radical innovation is largely not known beforehand. Moreover, the information asymmetries explained as market failures for technological innovation are virtually sources for change in the market place. In the real course, information is distributed unevenly. Entrepreneurs perceive innovation possibilities differently as well, depending on their personal experiences and knowing capacities. If everyone knows everything perfectly, there will not be any innovation to be developed in the first place. The notion of information asymmetries is actually saying that the concept of a perfect equilibrium market is incompatible to explaining innovation and change (Metcalf 1995:412-413).

Instead of organizing analysis around equilibrium and maximization, the evolutionary approach focuses on change and adaptation, in order to investigate why technological change proceeds endogenously and how technological competition serves as a driving force to structural change and economic development. This is the approach taken in the Schumpeterian tradition, developed in the post war time known as technological innovation economics. Firms are central as well in this tradition, they are the major actors in realizing economic value of knowledge in

the marketplace. However, with analytical focus placed on change, the assumption of firms being atomistic players with perfect information no longer holds. Firms are instead assumed adaptive agents, or learning agents. They behave as adaptive experimenter with imperfect information, adjust over time in face of a complex and changing world in which choices are vague, problems are ill defined, and outcomes of action are uncertain. Deductive decision making becomes impossible in such a world, and is replaced by inductively experimental behavior (Metcalf 1995: 450; Herbert Simon's 'bounded rationality' 1976). And relations with other agents become indispensable sources of information with which firms define and adjust themselves as part of a dynamic process in a whole system.

A broad range of inquiries are thereby opened as crucial for understanding how firms innovate and why do their innovative performances differ. These inquiries concern the process of decision making and adaptation, and factors which influence decision making and adaptation, such as firms competence in bringing in organizational and technological change; their network patterns and conditions in which resources for innovation are allocated, incentives to innovation are imposed, and characteristic co-operational and competitive relations are defined. Network effect, and the impact of firms structure on innovative performance become topics of increasing interest in light of the evolutionary view, as demonstrated in the OECD survey plan (see Section 1). It seems that with the widespread availability of information technology which lowers communication and coordination costs, network based small and medium firms structure in discrete manufacturing sectors gains additional advantage compared with more centralized firms structure. The former may possess a higher level of flexibility to adaptation. And innovation activities may be more widely dispersed in many centers in the former structure, so that it is likely more favorable to the development of specialization, which in turn deepens the overall innovative ability of the network.

In modern society, an important part of institutions specialized in knowledge generation and dissemination embraces universities, public R&D laboratories, technological consultant and extension institutions, and so on, or shortly, scientific and technological infrastructure and supporting institutions. The evolutionary perspective gives special attention to institutional structure of these knowledge generation and dissemination agents as well as the relationship of them with technological innovation at firms. It is found that science and technology are in complicated interactions, here science is meant the knowledge generation activities carried out in universities and professional research institutes with academic excellence as the major objectives, and technology the knowledge generation activities conducted at firms with the creation of utilitarian novelty being the purpose. The relationship between science and technology is inter-dependent, boundaries between them are blurred. On the other hand, science and technology are in principle necessarily developed in different institutional contexts, under

respectively appropriate motivations, competition rules, and reward criteria. This proposes a balanced development of science and technology, rather than an over-emphasis of one at the expense of the other.

In advanced economies, innovative firms have been growing and science and its institutions have been evolving rather naturally for a long time. The role of science for technological innovation has been also rather naturally mediated through various channels including labor mobility and informal relations between persons. However, the 1980s and 1990s see an emerging tendency in which purposeful coordination is perceived necessary to improve innovative performance of a national economy as a whole. The notion of national innovation systems is developed in response to the perceived need which we will discuss below. Insights developed from the evolutionary tradition provide much more relevant guidance for this purpose. For example, insights about fundamental science and engineering science, about generic technology and specific technology, and about codified and tacit forms of knowledge, are instrumental for policies in relation to knowledge generation and distribution efficiency, provided that knowledge is regarded one of the most important factors for modern economic growth.

Altogether, the evolutionary perspective investigates change and its mechanisms from two core elements: a) adaptive individual institutions that engage in various ways in the development and diffusion of knowledge for innovation; b) interactions between the adaptive individual institutions. The former embraces firms and supporting institutions, as well as education system and research and development system. The latter concerns inter-relations, or 'co-evolution' between institutions and technology at various levels of organizational structure. These two elements are the inclusion of the definition for national innovation systems used by the OECD NIS project, cited in the beginning of the paper. Pioneer authors on the topic of national innovation systems (Freeman 1987; Lundvall (ed.) 1992; Nelson (ed.) 1993; Edquist (ed.) 1997) also similarly use them.² With a great discretion given to behavioral, structural, and dynamic details involved in technological change, the evolutionary approach has been a school of multi-disciplinary efforts (OECD 1999b: 21). Centered on technological innovation, many research traditions have made contributions, including technological innovation economics and industrial economics, business management and firm theorems, institutional economics and organizational

² In their design by Nelson and Rosenberg (Nelson 1993: 4) which is for the country studies on national innovation systems published in the book, a national innovation systems is as "of a set of institutions whose interactions determine the innovative performance, of national firms." And innovative performance encompasses anything new to economic actors (mainly firms) in the system. Freeman (1987) has apparently focused his analysis of Japan on institutional dimensions. Edquist and his colleagues provide a comprehensive summary about their genesis and anatomy of various systems of innovation approaches, see Edquist ((ed.) 1997). Lundvall puts learning especially literally central in his two assumptions for the concept of NIS.

theories among others. Correspondingly, many of the contributing disciplines have absorbed the idea of innovation as a part of their research focus.

One may feel that the cited OECD definition reads too simple. It is in a way taken for operational purpose. The above interpretation may serve a footnote as how rich is the concern underneath the simple definition, and how the two elements combined make up a departure in directing research focuses from the conventional ways. In this regard, the two assumptions for the idea of national innovation systems made by Lundvall is worth being repeated here for an additional support. He literally emphasizes the links of knowledge and learning with modern economic development, and that learning is undertaken in an institutional context. The role of policy for accelerating learning is also emphasized upon the experiences of Nordic countries that were in catching up in the last century.

"First it (the concept of NIS) is assumed that the most fundamental resource in the modern economy is knowledge and, accordingly, that the most important process is learning. The fact that knowledge differs in crucial respects from other resources in the economy makes standard economics less relevant..." (Lundvall, in Lundvall (ed.) 1992: 1)

"Second, it is assumed that learning is predominantly an interactive and, therefore, a socially embedded process which cannot be understood without taking into consideration its institutional and cultural context. Specifically, it is assumed that the historical establishment and development of the modern nation state was a necessary prerequisite for the acceleration of the process of learning which propelled the process of industrialization, in the last centuries." (Lundvall, in Lundvall (ed.) 1992: 1)

Emerging Social Needs and The Policy Orientation of NIS

To better understand the NIS approach, it is necessary to see not only intellectual sources but also pragmatic problems that have an impact on the rise of the NIS concern. Originally there was no close link between technological innovation studies and policy making. Since the 1980s, the need for managing change and complexity of a national innovation system has become pragmatically vital. The idea of NIS therefore emerged with a strong policy orientation.

It was a shock to the advanced economies that Japan became a super power in the international market since the late 1970s, which was followed by so-called Asian Newly Industrializing Economies (NIEs). This stirred enormous studies on the Japanese system, and unique institutional characteristics in the Japanese system impressed researchers who did this. A consciousness about the importance of national institutional patterns grew, which is thought critical in bearing on innovation performance of a nation, more evidently reflected in Freeman (1987) and Nelson ((ed.) 1993). The rapid development and dissemination of information and

communications technology (ICT) created another challenge. Firms in OECD countries began, around the turn from the 1970s to the 1980s, investing vastly in new technologies, while productivity did not follow to increase comparatively. The lagged growth of productivity behind the pace of investment in new technologies, known as 'productivity paradox', required explanation (e.g. OECD 1991). Once again, studies in response to the productivity paradox show the importance of institutional change in order to harvest benefits from innovation opportunities opened by the advances in ICT and other new technologies, reflected perhaps more in Lundvall ((ed.) 1992). In the course, attention is indicated to interaction, or, co-evolution, between technology and institutions repeatedly. In addition, the development of new growth theories in the second half of the 1980s may have turned the majority mainstream economists to be participating or at least sympathized with the unorthodox approach of technological innovation studies and the search on NIS.

The notion of national innovation systems is not simply a summing-up of accumulated achievements in the direction of technological change. More than that, it is a synthesis reached at the aggregate national level, in response to the challenges as mentioned to the capacity of national policy making. Researchers have searched hard not only from Schumpeter, but also widely from classic and neo-classic schools (Lundvall (ed.) 1992; Nelson 1994, Freeman 1995, 1998; OECD 1998a; 1999b; 1999c), in order to interpret technological innovation and institutional change in linking with economic growth, and to develop necessary analytical methods. Apparently, to meet with pragmatic challenges was a critical drive for the NIS approach to come. It is hoped that the NIS approach provides a new way for science and technology policy making (Andersson 1998), which would be more integrated with economic policies, and more effective by various novel means in the promotion of innovative performance of a national economy. In short, the development of NIS is very policy oriented. It represents the effort in the introduction of policy innovation to the sphere of science, technology and innovation.

It is too early to conceive what will be eventually brought about by the NIS approach to policy making. We instead comment on some positive signals demonstrated in the OECD NIS project (OECD 1999b). Among the most remarkable is that networks and clusters have received high attention. This may well indicate the opening of an important policy area, for traditionally firms are seen operating separately. Besides, the recent decline in R&D investment in OECD countries may be alleviated to an extent. Some OECD countries, such as Finland, have developed means to increase public support to R&D. Because the NIS perspective proposes that maintaining a certain level of R&D is necessary for generating sufficient opportunities for innovation and selection. Furthermore, policy institutions and policy practices have, for the first

time, been surveyed systematically (OECD 1999b; OECD 1998b). This represents an effort to turn policy making towards a systemic and adaptive track.

From the evolutionary perspective, only an adaptive process carries effectiveness for a policy initiative. A policy initiative is aimed to introduce a social innovation, for which information is imperfect and choices are vague, just like a firm's initiator of technological innovation faces. The policy maker has to accept a considerable deal of indeterminacy and uncertainty in the consequence of the initiative. He must adjust the policy by learning about the working of the system over time. This flexible, adaptive policy mechanism devised by the NIS approach is in sharp contrast to conventional understanding of policy making: a policy maker conceived in the equilibrium view is obliged to correct the system deterministically upon his accurate maximizing calculation (Metcalf and Georghiou 1998: 80). Knowledge about policy institutions and policy practice hence becomes an important input to assist the policy learning process. So does widespread participation by publics in the policy process, which accelerates information flows between policy maker and the agents of the system in coordination. The adaptive learning policy process is therefore to be understood as an indispensable part of the NIS approach, owing to the complexity of the system and uncertainty that involves in a policy process.

In the introduction section, we have used the terms of policy themes, analytical tools, and policy institutions to describe the coverage of the OECD NIS survey. The three areas actually constitute a harmonious set of building blocks in order to put a new policy approach--the adaptive and systemic NIS approach on a solid knowledge basis. In the above paragraphs we also indicated that the development of the NIS idea was driven by emerging social needs for the improvement of adaptive capacity at national level in cope with accelerated technological innovation and international competition. With the impressive progress in all the three areas, we see that OECD countries are taking substantial steps to manage more effectively changes at the level of national innovation systems, steps that are necessary for the knowledge-based economic development, and hence have far-reaching implications.

OECD countries enjoy at least two kinds of advantages in the direction. A great deal of knowledge about technological innovation and institutional change has been accumulated there, together with richly developed expertise in a number of relevant research areas. The knowledge and expertise has quickly joined together to make contribution to the development of the NIS approach. The politicians and publics in OECD countries are also better prepared for participation in change. Having well educated population who are more apt at adaptation, the attitude towards change has been proliferated there and entrenched to ordinary citizens in the past decades. We hence do see a widespread acceptance of new theories and new approaches about technological innovation and social change prevailing in OECD countries (Andersson

1998; Caracostas 1998)³. This will serve an important social basis for further development in the NIS policy approach there, although turning to a new policy path will definitely have many difficulties to overcome.

An Evolutionary Theoretical Departure of NIS and its Enlightenment

Now a further review of the evolutionary perspective is necessary, provided that the NIS approach not only has its research tradition in line with the evolutionary perspective, but also requires broad social involvement in policy process to manage change. What should we prepare to see from the viewpoint of national innovation systems? And how should we work with the policy approach that the notion of national innovation systems devises?

First and foremost, a simply message is that by assuming a) that a system is composed by adaptive individual institutions and b) that these institutions are operating in interactions, the perspective of NIS has made a conceptualization of the systems in observation very differently from the way we used to take in thinking about the subject which we study. The perspective of national innovation systems conceptualizes complex dynamic systems, while the conventional perspective conceptualizes simple and mechanical systems, in which individual components of a system operate in isolation. Unlike simple mechanical systems where the state of a system can be deducted from the sum of individual components, complex dynamic systems evolve much more complicated.

Researchers in the fields of technological innovation and institutional change have for a long time observed 'peculiar' behaviours. Among the most distinct is *selectiveness* of change. Change occurs in a selective direction, but not randomly in all directions, because only that which is fitted to the particular interactive circumstances survives. Change, once selected, is often further enforced by adaptive learning in response to feedback loops which involves additional investment. Scholars have documented widely in relation to the selectiveness and self-organizing process of change, although in different contexts, and use distinctive terms (e.g. Nelson and Winter 1982; Rosenberg 1976, 1982; Dosi 1982). *Path-dependency* is a term (David

³ Caracostas comments it as follows: "In recent years, policy experts and policy advisors have been travelling around the world to spread the message (the linear model of innovation is dead). New theories and approaches about innovation and its social and economic embeddedness are challenging the well-known arguments that justify public intervention in research, development and demonstration activities. Based on evolutionary theory, systems of innovation approach and new knowledge about the social shaping of technology, these new ideas are progressively diffusing outside academic circles into the wider research and policy-making community" (Caracostas 1998: 308) Indeed, in an occasion which was for the inauguration of the Eindhoven Center for Innovation Studies in 1999 July, about one hundred people were discussing to each other on these new ideas. They were from academic disciplines, business companies, consultant agencies and government bureaus. There were debates of course.

1978, 1985; North 1990) which now receives broad acceptance. It emphasizes that a small historical event may matter if it has influenced the selection of a change that will be 'remembered' for a long time. *Unpredictability or uncertainty* (Kline and Rosenberg 1986) is also broadly observed. It may be better linked with radical changes, in which an expectation of the further state of a change is largely impossible to be made by referring to the past state of the matter. Please note that here we are inclined to merely make one point that evolutionary behavior of complex dynamic systems is peculiar in the sense that it seldom appears in textbooks, up to now.

With the introduction of the NIS approach, similar features of evolution are being discovered at the national systems level extensively. As mentioned in the introduction section, national innovation systems are found as country specific in terms of institutional structures, and measured in their specialization patterns in the areas of scientific basis, technological strength, and international trade. In addition, policy institutions, as well as policy portfolios and policy means differ among OECD countries. Viewed in a conventional point of view, these are all unorthodox. The evolution of national innovation systems is characteristically indeterminate rather than determinant, specific rather than homogenous as with respect to technology, firm, and country, and path-dependent rather than time-free and ahistoric. Confusion may occur in various ways if one's mind has not turned to be ready for the new approach of NIS. This may make the situation severer for scholars who were trained with traditional development economics. How to organize a survey on NIS in face of a system with many individual and interlinked institutions? What can be drawn from findings developed in a survey for other innovation systems, provided that innovation systems are country specific and path dependent? How to make policy recommendations upon a survey in the circumstance where nothing is regarded to be determined? In the following sections we will develop our argument in relation to these questions. Shortly speaking, policy analysis and policy recommendations become specific and dynamic as well, in correspondence to the conceptualization of complex and dynamic national innovation systems. An informative NIS survey has to be individually organized with clearly shaped inquiry and well-developed working hypothesis (Section 3). There is no universally applicable survey plan for different policy concerns. Cross-country comparison may offer references more in analytical methods and mechanisms about technological innovation and institutional change, than in concrete policy means (Sections 3 and 5). Policy recommendations have to be made upon detailed analysis for a specific purpose and in a certain context, and are subject to modifications over time (Sections 3, 4 and 5). Here, however, the single emphasis is to take into account the evolutionary theoretical departure of the NIS approach is a prerequisite for successful application of the approach.

Theoretically, the conceptualization of complex dynamic systems can be expressed as real,⁴ and pragmatically, the conceptualization is essentially closer to reality as far as societal change is centrally considered. In the most basic sense, the conception of complex dynamic systems is developed to distinguish them from simple mechanical systems. Nelson does so. Nelson suggests ‘a general evolutionary theory’ in which “[t]he focus of attention is on a variable or set of them that is changing over time and the theoretical *quest* is for an understanding of the *dynamic process* behind the observed change” (Nelson 1995, italic added), as a substitute for mechanically composed systems operating at equilibrium. Dynamic process is the key in his general evolutionary theory, which is caused by interactions between variables. Later on he (Nelson 1998) uses the succinct term of ‘co-evolution’ between technology and institutions to specify the interactions between variables. He thinks that an evolutionary theory as defined can be generally satisfactory to a number of themes related to technological change and economic growth, and that is in effect used for the definition of NIS.

Necessary theoretical concern about the systems which are composed by a number of interrelated units, has been noticed rather broadly. For example, Ludwig von Bertalanffy developed the notion of ‘general systems theory’ for those systems: ‘systems as sets of elements standing in interrelation’, and ‘systems of elements in mutual interaction.’ (von Bertalanffy 1979: 38, 45, also chapters 1, 2, 3, and 8). Laszlo (1973, 1987) terms his idea as ‘a ground evolutionary synthesis’ (Laszlo 1987: chapters 1, 2, and appendix) under a similar definition.⁵

⁴ The notion of dynamic complex systems is important and real. In a way, a dynamic complex system can be conceptually expressed as follows (ref. von Bertalanffy 1979: Chapter 3, and combined the treatment for catching up analysis taken by Fagerberg 1987). Here S is the measure of system’s state, Q1, Q2, ...Qn are system’s elements. The expression means that change of measure of any Qi is a function of all Q1, Q2,...Qn, and of the system’s state as well. And conversely, change of Qi entails change of measure of all other elements together with the system as a whole. Note that, if in the system novel elements are generated over time, and changes in the patterns of relations take place, n and f then should also be considered as functions of time. Moreover, suppose that changes of Q1,...Qi come not only in response to external shocks, but also from intentional action upon internal dynamics to make change, and so on, the picture goes even beyond the expression of the set of conceptual equations below. Nevertheless, the expression is in sharp contrast to those built on isolated elements with weak relations.

$$S=\{Q_i\}$$

$$dQ_i/dt=f_i(S, Q_1, Q_2, \dots, Q_n)$$

$$i=1-n$$

⁵ It is also interesting to see how Laszlo describes evolutionary behaviour by the systems under his ‘ground evolutionary synthesis’. We cite it as follows.

“The laws conceptualized in the evolutionary context are not deterministic and prescriptive: they do not uniquely determine the course of evolution. Rather, they state ensembles of possibilities within which evolutionary processes can unfold. They are rules of the game, to be exploited in each individual instances according to the skills and predisposition of the players. Dynamic systems--the ‘players’ in the game of evolution--are not strictly determined. They do not have individual trajectories (evolutionary paths--the words are *original*) but bundles of trajectories. If we consider all their trajectories starting from a particular region, no matter how

That such systems should deserve a theoretical attention is above all for the sake of the most distinct laws which govern their evolution. Hence for the evolution of national innovation systems is the properties of the laws such as selectiveness, path-dependency and country-specific. The evolutionary synthesis of NIS is indispensable to recapitulate the real world that moves to rapid change in unprecedented pace, and that meanwhile undermines indispensably the conventional laws of determinism.

To conclude, in this section we have repeatedly explained that the notion of national innovation systems is in line with evolutionary theoretical approaches to the phenomena of technological change and economic growth. It emphasizes the dynamic and complex nature of innovation systems, and diverges fundamentally from conventional ways. The notion of national innovation systems is developed in response to the needs for social capacity improvement in cope with change and complexity. Policy innovation is made possible thereby, this however requires a corresponding change in the ways in which we think and act, towards adaptive and dynamic as well. People from developing countries are relatively disadvantageous in the preparation for the change. Without such a change, the notion of national innovation systems is felt very uncomfortable to deal with, as if it puts various different subjects into an empty box. This is because the standpoint of traditional modeling is still taken as the reference point in which the causal relation of a subject is defined in a determined way. We now turn to discuss methodological specifics of the NIS approach.

small, then we find that these trajectories separate after a time into quite different regions. As Nobel-laureate thermodynamicist Ilya Prigogine points out, dynamic systems have a basic 'divergence property'. This property undermines classical determinism, based on the concept of a single trajectory. Given identical initial conditions, different sequences of events unfold--within the limits and the possibilities set by the laws. The sequences in turn create fresh sets of limits and possibilities. Evolution is always possibility and never destiny. Its course is logical and comprehensible, but it is not predetermined and thus not predictable." (Laszlo 1987: 20).

3. METHODOLOGICAL SPECIFICS OF NIS

This section gives a brief review of methodological characters involved in a survey, which emphasizes on change and its reasons and covers a number of related units, namely innovation systems. Innovation systems need not be definitely national, regional innovation systems, technology systems, and clusters are all possible survey subjects, they are more or less subjects of aggregation, and often involve policy relevance. As has been made clear, the concept for innovation systems is different from traditional modeling of a subject. The concept of innovation systems is comprehensive and indecisive. It catches the complexity of systems, provides important guidance towards component units and their relations, precludes that merely measuring a system at aggregate level could reveal enough causal links. But, it in itself does not contain a survey plan in detail. Accustomed to do research in some disciplines for example mainstream economics, one may feel difficult to handle the comprehensiveness and indecisiveness. He then tends either to doubt the NIS idea if it is scientific, or deal with it in other ways.

This section discusses methodological specifics of NIS approach in general, with a special attention given to problems that have been, or might be, encountered in a study on developing countries. Methods used for a NIS study are specific in that micro-foundations constantly constitute a large part of the survey, which are assumed containing reasons and rules for explaining changes observed at aggregate systems level. Besides, each survey has to be in principle specifically designed. The purpose (quest) is to be clearly set up, the analytical framework to be developed, and hence the analytical boundaries delineated. There is no survey plan immediately and universally applicable. This methodological specifics of NIS approach is determined by the underpinning dynamic complex systems conception of NIS, uniquely distinctive from conventional approaches. We devote this section mainly to readers from developing countries, with the belief that methodological principles are part of the notion of NIS. A discussion on methodological specifics provides an additional interpretation of the NIS approach, useful for the application of the NIS approach in different circumstances.

Surveying Micro-foundations for Explaining Aggregate Systems

By the very nature, the definition of complex dynamic NIS is characteristically 'holistic' (Edquist 1997: 17-18). A systems (reads 'evolutionary') approach invariably develops specific methods designated to cope with the unconventional and indecisive conception. A basic principle for the systems approach may, with little disputes, be described as *surveying micro-*

foundations for explaining aggregate phenomena. This is an indispensable principle, has been regularly taken in technological innovation studies, no matter the author has, or has not, specified a systems approach he adopted (e.g. Carlsson and Jacobsson 1994; Shin 1994). This is also taken in many other professions, among which historians have long been working on it. The OECD NIS project has been focally developing methods and indicators in this direction. However, it is a useful starting point for a discussion on methodological specifics of the NIS approach.

Consider Michael Porter's *The Competitive Advantage of Nations*. Interesting is why and how he developed it. He was, when he took a policy advisory position to the U.S. Government, stirred by his dissatisfaction with the conventional notion of competitive advantage, which rests on static, or 'lower ordered', input endowments. His puzzle was that '[m]erely using the resources available, or assembling more resources, is not enough for prosperity. Neither is redistribution of a nation's wealth between interest groups.' (Porter 1998: xii). From this he takes the hypothesis that the competitive advantage (reads as 'long term') of a nation rests on the ability to 'productively use and upgrade its inputs', namely, the creation of new and higher ordered input endowments. His survey strategy then goes to lower levels. He analyses the elements of a national economy--firms and industrial clusters, and puts them in the context of interactions between various factors of the 'diamond' (system), including firm strategy, structure and rivalry; factor conditions; demand conditions; and related and supporting industries. His concern about the importance of micro-foundations is also relevant to developing countries. He himself has commented that '...macroeconomics reform is necessary but not sufficient. As important...are the microeconomics foundations of development.....What next? What to do after macroeconomics stabilization and adjustment (?)...' (Porter 1998: xvi). We will return to this topic in Section 4 and 5, address it from the perspective of NIS.

Table 1 depicts the composition of the methodological 'surveying micro-foundations for explaining aggregate phenomena', by compiling the NIS approach and the Porter's. The entries used are organized by referring to Nelson (1995, italic added): "The focus of attention is on a variable or set of them that is changing over time and the theoretical *quest* is for an understanding of the *dynamic process* behind the observed change." Hence, 'major quest and hypothesis', 'analytical unit', and 'dynamic process/cause' are entries appeared in the left column of Table 1. The additional entries 'disciplinary background' and 'policy orientation' are used for the inclusion of Porter's work, in order to extend our understanding beyond merely NIS. From distinctive disciplinary backgrounds (technological innovation and business management here) and at distinctive policy orientations (science and technology policy for innovation and trade and business policy respectively), concerned people come to a commonplace. There is a shared scholarly aspiration here, which regards how to better manage

dynamics and complexity of the subjects, and a shared methodological principle, which gives attention to lower levels of a complex subject for explanation, though both of the two approaches should be said still in primitive stage of development.

To study on micro-foundations and link it with aggregate phenomena is an essential part of the holistic conception of NIS. A simple definition of NIS, and an emphasis of its evolutionary reasoning, by no means implies to downgrade substantial details of individual systems into a homogenous trunk. Just the opposite occurs. A synthetic conception of NIS, incorporated by the principal method of analyzing substantial details which are distinctly specific to particular systems, tends to best differentiate specific attributes between innovation systems, as has revealed in the OECD NIS survey. Spectacular findings of the OECD NIS project are virtually in country-specific patterns in every facet of their NIS--in scientific basis, in technological specialization, in international trade, and in policy institutions. The NIS approach takes large part in micro-level studies, it can not be understood and applied appropriately without acknowledging this intrinsic methodological principle. In this connection, it is necessary to notice that merely pooling out aggregate data is an inappropriate down-play of the NIS approach. A rejection of the NIS approach because of the comprehensive and indecisive conception the NIS takes, is pointless.

Table 1: Analytic characteristics: The NIS approach and the Competitive Advantage of Nations

	NIS	The Competitive Advantage of Nations
major quest and hypothesis	The improvement in learning efficiency is the source for innovativeness of a nation	The creation of productivity growth is the source of the prosperity of a nation
analytical unit	--nation --cluster (industry, region) --firm --public knowledge institutions (S&T and educational infrastructure) --knowledge network, technology system	--nation --cluster (industry, region) --firm
dynamic process/ cause	Interactions (co-evolution) between technology and institution: technological trajectories; life cycle theory of technology; path dependency; learning by doing, using, and interaction; knowledge distribution power	Interactions among the elements of the 'diamond': firm strategy, structure and rivalry; factor conditions; demand conditions; related and supporting industries
discipline background	Technological innovation	business management
policy orientation	Science and technology policy	trade and business policy

Sources: Porter 1998; Lundvall (ed.) 1992; Nelson and Rosenberg 1993; Nelson 1995; OECD 1999b; Carlsson (ed.) 1997.

Dynamic Delineation of Analytic Boundaries

Provided the importance of micro-foundations, analytical difficulties arise concerning how to define analytical boundaries. A straightforward way is following a geographical space such as a nation's territory for a national system, a region for a regional system. This is far from workable, because of the great complexity of the systems, also because inter-national and inter-regional relations may be significant. This is called the boundary-delineation problem, much less seriously encountered in conventional analyses. In the exercise of the OECD NIS project, the boundary-delineation problem seems more apparent to the Catching-up Group (Mowery 1998).

Instead of stationary delineation, *dynamic delineation of analytic boundaries* is to be considered a better approach. Namely, those elements and relations if dynamically significant to the analytical focus of a survey, should be covered in the study. Here we suggest two dynamic boundary-delineation approaches: a) following a historical process to take *the historical perspective of boundaries delineation*, and b) around a quest to go to *a quest-guided delineation of analytical boundaries*. Surely the distinction between the two is only a matter of degree.

The historical perspective. Following a historical perspective to determine the scope of an analysis, the element of quest unavoidably involves but its involvement is usually rather general. With the inquiry 'how a certain system gets where it is now', events and factors that have induced and ruled out changes with which the system moved through a path are the focus. The boundaries of the survey are dynamically delineated according to the significance of the role the events and factors have played. Here, consistent with the evolutionary conception, time dimension is central. The historical perspective gives a reference for boundary definition upon the power of evolution in such a way that changes unfold themselves with time. Examples of this are Mowery and Rosenberg (1989) and the country cases in Nelson (1993). Slightly differently organized but in a similar vein, the study on 'technological systems' (Carlsson and Jacobsson 1997; Carlsson (ed.) 1997) can be considered of the historical approach as well. Time dimension is central also, with an inquiry focusing on a technology, whose development is divided into different stages. Functional analysis is carried out to examine the relationship between the development of the technology and the roles played by various actors and supporting institutions, stage by stage. The scope of analysis is defined by the dynamic importance of actors and institutions in relation to the development of the technology in real terms. They choose to analysis the technologies of generic importance such as factory automation and electronics. The scopes of the technological systems are all rather large, and in change over time.

Quests and working hypothesis. Alternatively, a survey may need to be organized more around an inquiry--a quest, in which time dimension turns to be secondary. How to phrase a quest, or what is

the appearance of a quest, and how to make up a survey with the quest, are appropriate items to the quest-guided solution for boundary-delineation problem. Up to now, well-documented studies under the call of national innovation systems are only a few. For getting an allusion, we go to Edquist (Edquist (ed.) 1997).

There are three cases in the Edquist's book in which a quest has been setup and an analysis done upon the quest, we shortly summarize them in Table 2. Some other cases are not included as they seem to be a proposal, not exercised yet, such as that by Anderson and Lundvall (242-265) which is for computer simulation of firmsevolutionary process in an industry in terms of capital stock, productivity, and concentration.

We find that for each quest a development of a set of working hypothesis must be associated. It is not a quest alone, but *a quest and a set of working hypothesis together that makes a survey productive*. In the meanwhile, an analytical boundary is accordingly reasonably well defined. Quests, as shown in each case, seem to have to be very specific. Each quest examines one particular aspect of 'relations', between technology and institutions: the relations between firms characters and trade specialization, the relations between technological 'regimes' and country-specialized allocation of innovation, and the relations between knowledge distributional power and national institutional characters, respectively in the three cases as listed in Table 2. Obviously there is no universally applicable quest, just as there is no working hypothesis which would be widely appropriate to whatever inquiry raised. Working hypotheses are not included in the table, for otherwise the table would be too complicated to be clear. Some remarkable facets of working hypotheses however can be summarized including: a) that a working hypothesis is specific to a certain quest; b) that a working hypothesis should contain a workable survey plan and analytical framework; and c) that the formation of a working hypothesis entails enormous knowledge input, knowledge that has been accumulated, and is often multi-disciplinary, depending on the focus of an analysis. In each case, a considerable part of their work reviews about learning process, knowledge flows, technology and technological innovation, firms and industrial structure, supporting institutions, and so on, to clarify the quest and to search for and to validate the working hypothesis. Apparently, this demonstrates that the sophisticated capacity of NIS analysis has to build on the achievements long developed mainly in the direction of technological innovation as sketched in Section 2, and there is a gulf here in terms of learning experiences for researchers from developing countries, for we were basically aside the accumulation process.

Table 2: Quest illustration

Author	quest	objective
Guerrieri and Tylecote (107-129)	the relations between behavioral characters of firm management, their environment conditions of home country, and the country's pattern in technology and international trade specialization	cross-country comparison
Breschi and Malerba (131-156)	the relations between Technological Regimes (indicated by a number of characteristics of technology) and geographical distribution of innovations in various sectors	cross-country comparison
Foray (64-85, also David and Foray 1995)	the relations between distribution power of knowledge and institutional characters. This has been taken as an important part of the quest for the OECD NIS project	cross-country comparison

Source: Edquist (ed.) 1997.

An interesting point is about cross-country comparability. Although analysis of NIS is not necessarily designed to make cross-country comparison, the proposal by Anderson and Lundvall is an example, all three cases have the objective of cross-country comparison. A note is needed as follows and it seems plausible by the fact that all of these authors are among major contributors to the recent development of NIS as well as to the development of the OECD project. That is, to an extent the cross-country comparative objective here is a reflection to the purpose (quest) of the OECD NIS project (OECD 1999b: 3): knowledge distribution power of national innovation systems (Foray in Edquist (ed.): 64-85, also David and Foray 1995), and testing it upon cross-country comparison along with the development of a set of indicators, though the project as a whole embraces additional objectives. Knowledge distribution power may have seized a critical aspect of policy demands encountered by the majority of OECD countries, in face of accelerating technological progress (notably ICT) and tightened international competition. This focus is therefore one of high policy relevance to them. The focus is however less intimately policy relevant for the Catching-up Group particularly,⁶ and for less developed countries in general. For sure an investigation following the design may generate

⁶ To ask 'how to transform a large government-run industrial technology R&D system in a radical transition period of economic regime?' 'what is the impact of the specific international trade and export-manufacturing regions on domestic innovative activities?' and 'why economic miracle occurred and what have been the reasons of the national innovation system for both past success and current crisis?' would be quests more specific than ask what are the national innovation systems in Hungary, Mexico and South Korea, for example. This was learned by the author in attending the Catching-up Group meeting of the OECD NIS Project, June 1997, Paris. Also see Mowery 1998. The Catching-up Group is not the major part of the OECD Project. For the majority of the participating countries, the focus is around knowledge distribution power of the systems.

useful information, and all developing countries, if being able to do this, may benefit, but such information might be more the kind of background information. Much more work is indispensable if it is to be valued in the context of their country-specific problems.

Another point is that a productive quest captures pressing policy concern in relation to growth and development. Or in other words, *policy relevance is an important element for a quest to result in productive consequences*. Because the study on NIS entails enormous resource input, policy relevance legitimates the use of necessary resources. More critically, policy relevance instigates positive loops, hence increasing returns to investment in a NIS study, by widespread participation and knowledge sharing between academics, policy makers, businessmen, scientists and technologists, and others. This is actually a scenario presently emerging in many OECD countries. To explain this by evolutionary theory, a policy relevance of a quest is a necessary condition for a policy learning process to occur. Moreover, cross-country comparison may mainly, or perhaps merely, be meaningful under shared policy concerns. Because, highlighted by the perspective of NIS, innovation systems between countries are not homogeneous, but in different patterns in terms of specialization and institutional structures. The merit of cross-country comparison may well be in that it informs where is the limitations rather than it guides to imitate superficially. Search cost reduces for certain policy initiatives, while the workability of any important policy initiative will eventually be determined through co-evolution in particular country-specific circumstances.

We end this section by making a general comment on the *relativeness* of our knowledge about innovation systems. The evolutionary perspective of NIS rules out linear-kind deterministic laws with respect to evolutionary behavior of innovation systems. It also intrinsically declares that our knowledge about innovation systems will never become perfect. This is simply because novelties--new technology, new institutions, and new patterns of relations--are being created ever dynamically in innovation systems. And in front of the great dynamics and complexity, the capacity of our knowing is limited and bounded. Compared with thirty years ago for example, multinational companies, an important carrier of international technology flows, have changed their behavior dramatically. Their objectives of international sourcing have turned to attempting for 'global integration', from merely seeking for low wage labor in earlier times (Ernst 1998). Our knowledge has to be renewed and working hypothesis to be modified if a study in this regard is to be instructive. One may wish, following conventional understanding of knowledge development, that a succinct normative evolutionary theory with elegant formulation and broad explanatory power might be developed upon rich enough appreciative knowledge from empirical studies. However, to be sympathized, such an attempting must tell us where it is going to generalize--it must be towards assisting for better comprehension of diversity, specificity and relativeness, but not the reverse side. Our review through the section indicates that in studying

NIS, the setting-up of certain quests, the development of certain working hypotheses and survey frameworks, are all conditioned. Research cases on NIS, however nicely organized, may only offer useful reference, but should not be taken for granted. This seems to be remembered as the key for 'latecomer' analysts of NIS, especially from developing countries. In a similar manner, Lundvall has commented for methodological flexibility and openness (Lundvall 1993: 13). Indeed, the conception of innovation systems has put a greater hardship in intellectual labor on its students.

4. ECONOMIC CATCHING-UP: HISTORICAL TRANSITION AND NATIONAL INNOVATION SYSTEMS

In the previous sections we have attempted to make clear what were the intellectual sources of NIS approach, how the idea of NIS became socially accepted for policy purpose, and what underpins the methodological principles. Our purpose is to shed a light on where adaptive efforts are most necessary if the NIS approach is to be a useful policy instrument for developing countries.

Although nobody would state literally that science and technology play no role, and change and technological innovation has no relation with economic development in developing countries, the experience with science and technology has been very diverse there. The huge investment in science and technology made in India, Brazil and China for example, did not prove successful economic development. Presently, the policy attention of developing countries is towards balance, just in the opposite of OECD countries where the moods of politicians and academics are moving towards change. This has of course its historical reasons, but clearly there lacks the sense about change in this part of the world, which the notion of NIS emphasizes.

In this section, we first make a quick, unavoidably partial, review on thoughts about economic development, titled *Various Thoughts about Economic Development: Controversies between Theory and Practice*. In the past half century with the uneasy proceeding in development practices, theories and ideas were generated, accepted and tried, and replaced, but all were around capital accumulation. We then, in the second part: *Historical Transition and NIS in Developing Countries*, turn to take a review of recent progress in the mainstream development economics, especially the work by Fei and Ranis (1997). We find that in their ‘an evolutionary framework’ of economic development an important step has been made, which is sensible to micro-processes of productivity gains from structural change and technological innovation. This provides a necessary theoretical foundation upon which an NIS survey is able to be communicated with development economists. This is followed, in the final part of the section, by a development of some characteristics of NIS in developing countries in general, by drawing upon both the Fei and Rains evolutionary framework of economic development, and the OECD framework of national innovation systems.

Various Thoughts about Economic Development: Controversies between Theory and Practice

With respect to economic development of less developed countries, a perception of the status of 'late industrialisation' distinguishes the developmentalist view from other traditions which withhold any principal differentiation in research focus in dealing with development issues. The developmentalist thoughts have an origin from the experiences of earlier 'late' industrialization (late to England) in Europe and North America. Their major arguments, taken by such as Veblen (1966) and Gerschenkron (1962), are that there are advantages for economically backward economies in relation to the possibility of borrowing technology from advanced countries. But these backward countries are disadvantageous in inherited obstacle institutions that hinder the process of borrowing and catching up. Government intervention is therefore necessary in supporting the creation of banks and in protecting infant industries. Contemporarily (not to mention about early post-WWII time), researchers who stand in the line are very much relying on the successful experiences in East Asia. Amsden (1989) for example, contends, by referring to South Korea, that late industrializers in the twentieth century are positioned even more difficult. Compared with earlier industrializing followers like Germany and United States which had in the same time of borrowing been able to generate new technology, the twentieth century latecomers possess only low waged workers possibly together with education, but not a technological edge. With low wage advantages they start to industrialize and penetrate into the international market because of strong government intervention such as to get the prices deliberately 'wrong' (in favor of targeted industry), special structure of firms such as vertical integrated but on fields with less technological links, and the strong role of managers and engineers in shop-floor, to promote learning from borrowing. Although no rejection is raised to the fact that learning from borrowing foreign technology entails special efforts, not much progress has been made systematically as well with respect to how specific learning efforts are to be made upon borrowed technology, except individual cases. Alongside have been continuing debates on what the government should do, and what needs to be left for the market.

Conventionally, based on a general production function, physical capital investment has been regarded the major component for economic development. It, in the simplest form, is expressed in the Harrod-Domar model⁷. This model, assuming population growth is stable, indicates the single factor that determines what level of income a developing economy can reach is the ratio of capital to labor, and had been used as the instrument of development planning. Policy

⁷ For latest summaries on Harrod-Domar model and its modifications, and various sources of theoretical thinking of economic development, see Hayami (1997), Fei and Ranis (1997).

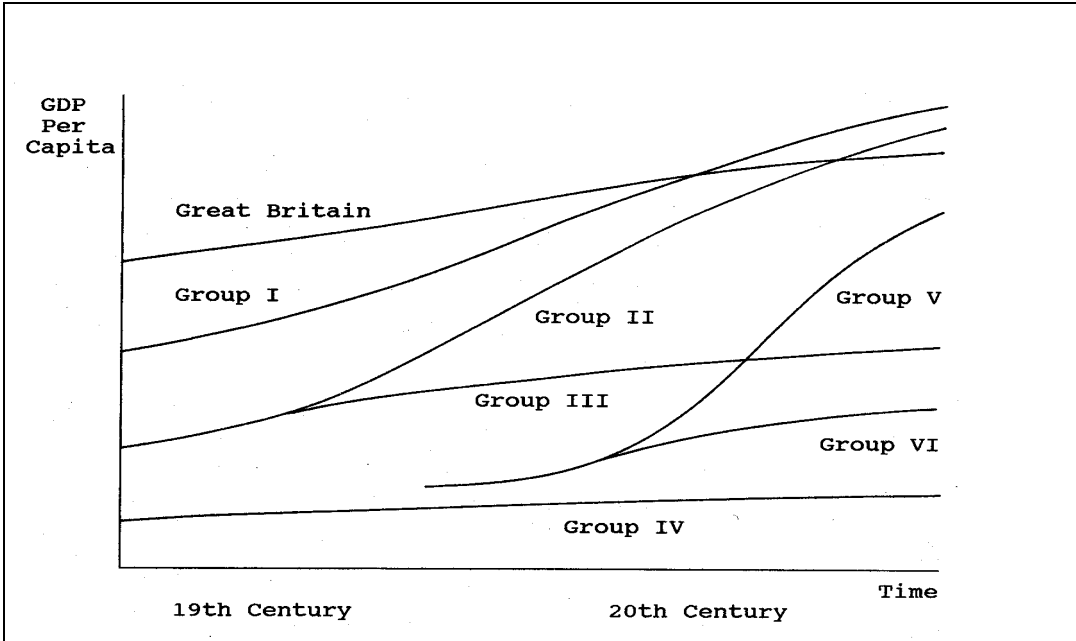
recommendations derived have been centrally towards saving, for saving rate determines capital investment rate and hence growth rate. This over-simplistic conception of course contradicts the practice of economic development. For example, it predicts that, a developing country saves about 12 to 15 percent of their income from the previous average of 4 or 5 percent would enjoy self-sustainable growth. But the domestic saving rates of the low-income countries have since the 1960s been higher than 15 percent, nobody would agree that a state of 'self-sustainable' development has been achieved in these countries (e.g. Behrman and Srinivasan 1995a: 2112). Enormous modifications have been made later on with the simplistic Harrod-Domar model, and economic planning of early day's type ceased, problems remain which come from the basic conception of production function. Institutions are excluded, technology is expressed on a general abstract level, and few insights have been able to be developed as regarding how technology is gained, absorbed and improved in the process of development (Evenson and Westphal 1995). Technology is not homogenous and general at all. The acquisition of technology from borrowing is not a smooth process as the production function expressed which involves heavy investment in absorption and adaptation.

Different perspectives predict the possibilities of catching up differently. Those who take a developmentalist view of economic development, and those who are concerned with the importance of technology and institutions, would expect divergent consequences among economic latecomers. Alternatively, Harrod and Domar, the neo-classic view, would predict that poor countries, with roughly similar rates of accumulation in factors, will grow faster and eventually catch up to the economic leaders. The new growth theorists would be rather pessimistic in contemplation of catching up, because these theories attach the importance of dynamic economies of scale to growth which is in favour of richer countries where the investment in physical and human capital has accumulated much higher. Hence richer countries have been endowed much greater the potential in generating higher growth with similar additional investment (World Bank 1993: 409-50). This can be called a gap-widening view in its theoretical logic. Figure 1, cited from Hikino and Amsden (1994),⁸ illustrates an overall picture of catching-up, forging ahead and falling behind, since the nineteenth century. Great Britain is the pioneer of industrial revolution, Group I refers to the innovators in the second Industrial Revolution particularly the United States, Group II the nineteenth century followers typically Nordic countries, Group III the nineteenth century cases of 'stumbling back' typically some Latin American countries, Group V the twentieth

⁸ Maddison (1994) gives a similar depiction while his grouping of countries is slightly different.

century followers especially Japan, South Korea and Taiwan, Group VI the twentieth century cases of ‘stumbling back’, and finally Group IV, which are those typically in Sub-Saharan, still under-developed.

Figure 1: Later Industrialization in Historical Perspective



Source: Hikino and Amsden 1994

Apparently catching up does not cease entirely, the new growth theories seemingly hold inadequate comprehension of the possibility in successful catching up. On the other hand, converging with the productivity leaders has not yet happened to the majority of the current developing countries, with only a few exemptions, notably South Korea, Taiwan, and Japan. This means that the prediction of neo-classic theory is far afield, and the new developmentalists should be said being nearer to the reality, by their appreciation that there are particular difficulties associated with the twentieth century’s industrialization, hence extraordinary measures are necessary to transform a developing economy qualitatively.⁹ Beyond these, the

⁹ Baumol (1994) contends for a ‘contagion’ model of convergence in contrast to the ‘common-force’ mechanism. The so-called common force mechanism is the well known neo-classic construction in which the central common force is that of diminishing returns to capital, and it predicts that all countries move to a common steady state if all countries have identical technology and saving rates. The contagion model of convergence on the other hand, heavily draws on empirical observations, gives strong value to local (i.e. ‘ancillary’ in his term) variables and the presence of relationships and feedbacks between variables during the process of economic growth. It hence accepts that ‘...each economy will have its own steady state, and the pertinent variables will never converge completely.’ This model is, through somehow vaguely expressed and difficult to read, virtually seeing economic growth as the behaviour of

behaviour of the dynamic convergent West groups warrant a notice. The West groups¹⁰, the Great Britain, Group I and Group II expressed in Figure 1, have enjoyed convergence to each other over a long time, through waves of hedging ahead or falling behind. Each wave changed technology and productivity leadership among the groups, the gross trends of convergence however have maintained by a strong force which spread an appreciable acceleration in growth to relative followers (Madisson 1991). Highly developed societal, intellectual and institutional capacity to cope with change is the major explanation for the dynamic convergence, a capacity that had, as argued, begun to develop within them not only since the Industrial Revolution, but over the preceding several centuries of 'proto-capitalist' development. The shared tradition among them from Renaissance and Enlightenment is also remarkable, that awoke the consciousness of human's creative capacity and gave birth to modern science, that prepared the minds and means necessary for taking action to transform the forces of nature through investigation and experimentation (Maddison 1991: 52-55; Rosenberg and Birdzell 1986). In short, catching up is not a matter of merely quantitatively expanding production capacity. It is much more a matter of turning a less innovative economy towards as dynamic and innovative as the convergent groups. Capital accumulation is not convinced to be the engine of modern growth, nor is international trade.

But trade liberalization is one of the major policy orientations currently prevailing in developing countries, with the hallmark being the aggressive World Bank and IMF Structural Adjustment Programmes (SAP) implemented since the 1980s. The balance-of-payment problems of international trade were one of the major triggering factors (see Kruger 1995), which were associated with high inflation in many Latin American countries, and hence the purpose of SAP was directed heavily to 'economic stabilization' (Kruger 1995: 2511). Theoretical reasoning for SAP, although sophisticated, has been centred on the role of market mechanisms to promote efficient resources allocation and technical progress, or 'getting the prices right'. The result of the SAP is diverse however--roughly that: a) trade liberalization has positively led to the reduction of price-cost margins in import-competing sectors where previous distorted competition status misled the allocation of benefits hence the (static) efficiency of resource allocation; b) but the impact of trade reform on structural rationalisation has not been so apparent, for change in industrial structure relates to intra-firm restructuring as well as entry and exit of firms; c) trade reform shows correlation with the growth in TFP of incumbent firms in many cases which is called technical efficiency (for points a, b, and c, refer to Rodrik 1995;

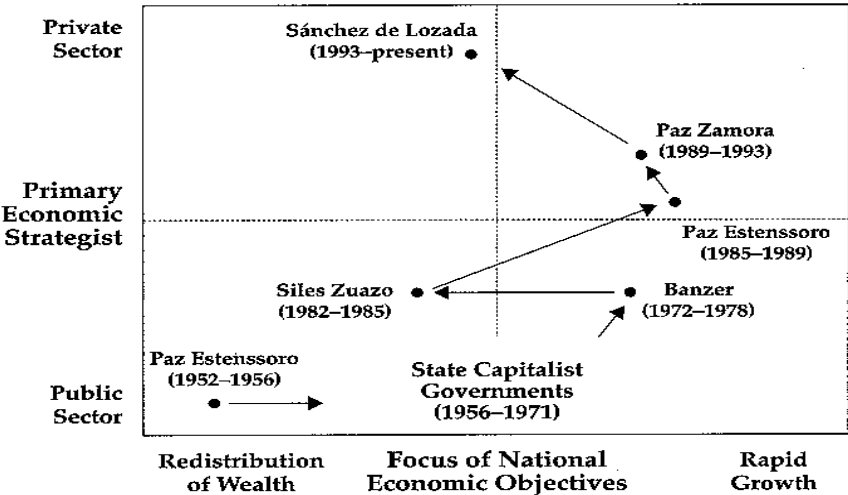
dynamic and complex systems. A short review of convergence growth hypotheses can be find in Sehrman and Srinivasan (1995: 2491-2493).

¹⁰ We take the notion for the 'west' or 'capitalist' group as that of west and north European countries and their 'offshoots', as Maddison does (1991).

Behrman and Srinivasan 1995b); and d) investment in R&D has been declined in all developing countries, most serious is in Sub-Sahara. Especially notable is inadequate and declining investment in agricultural technology and extension services (Enos 1995). An acceptable general conclusion goes that ‘getting prices systematically and significantly wrong that import-substituting countries have done in the past has been a costly mistake. But few would disagree that getting prices right, in itself and of itself, will be sufficient to make Bolivia or Ghana grow at Korean rates.’ (Rodrik 1995: 2971-2972).

It is useful to have an impression how dramatic policy shifts have been taking place in developing countries during the past several decades, as depicted in Figure 2 which is for Bolivia (Fairbanks and Lindsay 1997: 182-185). The horizontal axis represents two aims of national economic objectives which are growth-focused and equity-focused, showing the growth-equality dilemma which has long been faced by development governments indeed (Little 1982: 209-217). The vertical axis represents the actors assumed to play a major role for a certain policy objective, which include several combinations: the government and public sector under the import substitution strategy, private sector under the free market strategy, and a mixture of the two under the open-to-international trade strategy as the authors term them. And the notes above each time period are names of Bolivian presidents respectively. One may be wondering, beyond and above all, the dramatic policy shifts seem to evidence that there are missing elements in the conventional theories of economic development. Partial, simple factors based reasoning for policy making may have had a contribution.

Figure 2: Bolivian Economic Policies over Time



Source: Fairbanks and Lindsay (1997: 182)

Historical Transition and NIS in Developing Countries

A synthesis is called for with respect to economic development in contemporary late industrializers. Economic development of developing countries can not be effectively conceptualized mainly with static efficiency, in face of an increasingly rapidly changing world in which developing countries are a part. More fundamentally as is demonstrated above, dramatic, historical transition entails profound institutional, structural and technological changes which must be central of a liable theoretical framework. To develop a synthesis of this kind, the new growth theories can not contribute much, for these are theories which analyze the qualities of an one-sector world of the mature modern economies (Fei and Ranis 1997: 44). The tradition in technological capability building (Pack and Westphal 1986; Ernst, Ganiatsos and Mytelka 1998) has not yet contributed much also, for although with some influence, it has been rather alien to the mainstream of development economics. Nevertheless some progress has emerged and we take the work by Fei and Ranis as our major reference.

Fei and Ranis' Transition Growth: An Evolutionary Framework of Economic Development

Several components make up their 'an evolutionary perspective' or 'an evolutionary framework' for analysing growth and development in developing countries (Ranis and Fei 1997).¹¹ Of central importance is the notion of 'transition growth', which means that the development of a developing country has to pass through the transition from a pre-modern pattern towards a modern pattern of growth. Transition growth therefore differs a developing economy from an advanced economy in that the latter growth proceeds under relatively united and stable rules (*ibid.*: 6, 372). To be sensible to the complexity associated with the process of transition growth, a 'classic' emphasis is revived, directed to micro-economic analysis of productivity gains. It is believed that the sources for the productivity gains are combined from the classic (Adam Smith) division of labour, and the modern (Kuznets, Schumpeter) science and technology based innovation, though their own case analysis does not touch upon innovation directly (*ibid.*: 44, 45, 26). Methodologically, as we argued earlier that methodology is a part of concept, Fei and Ranis go to a sub-phase based 'holistic' scheme. Sub-phases in a transition growth are distinguished, in their exercise it is made upon the experience in Taiwan. It is believed that distinguishing sub-phases and assuming that rules of operation and forms of

¹¹ I am grateful to Norman Dytianquin for his reminding about the work by Fei and Ranis timely. We felt that some progress like Fei and Ranis made should be a necessary precondition, for the NIS study to be useful for developing countries.

structure change over sub-phases is the logical necessity of an evolutionary perspective. 'Holistic' aims to open the treatment in which details from microeconomic analysis is able to be integrated so as to achieve a comprehensive understanding of the economy as a whole. In addition, an interesting point is about motivation. Fei and Ranis are encouraged (*ibid.*: 45) by the historical experience in Japan and the recently emerging NIEs. The feasibility of successful historical transition has been demonstrated, and they believe that unlimited potential of science and technology will ultimately help to 'lift all the boats' in the developing world. There is no reason for being pessimistic but every reason for making efforts, hence their innovation on the evolutionary perspective.

This is really a celebrated progress, considering the way it takes in thinking and studying on a complex and changing process of transition growth. As we have learned from the OECD experience, the multi-disciplinary knowledge based NIS has been developed resulting from a long period of accumulation of a number of intellectual fields related to the theme of change. The accumulation has been less difficult, even alongside the neo-classic tradition, because the modern growth pattern offers a comparable basis. A (small) step forward in modeling growth as made in the new growth theories may have a big impact, let almost every one feel little uncomfortable to turn to change. But there is no such a historically constant basis there in the developing world. Historical transition, in which growth faces historical difficulties and through which growth paves ways towards historically new forms and rules, characterizes late industrialization of old times, and more so of the contemporary era. By and large, historians like Veblen and Gerschenkron, and scholars who take a developmentalist view such as Amsden and Robert Wade, perceived the historical transition character of late industrialization. The insights however were not integrated into mainstream development theories. Among economists, those who analyze economic growth in very long spans of time are better aware of the transition nature, such as Madisson (1991), Ohkawa and Rosovsky (1973), and Hayami (1997). The latter three authors are concerned about Japan. In their work, an analogous sense of transition growth, or historical transition, of the Japanese economy, has been clear.

In this connection, the contribution by Fei and Ranis is revolutionary though still in a primitive stage. Beginning with dualistic structure of developing economies they have been sensible to the centrality of historical transition, and eventually achieve a synthetic framework which has the qualities in: a) acknowledging the complexity of economic

development which is qualitatively heterogeneous over time; b) interpreting aggregate performance upon micro-process; c) corresponding with the achievements developed in the mainstream economic analysis, mainly production function based growth and productivity accounting. Such qualities which the evolutionary framework of Fei and Ranis' possesses are gained by means of dismantling uniformed deterministic causation, and restructuring pieces of insights into a framework with 'organized' complexity. Feasibility in coping with change within and between sub-phases is thereby open. Intellectually this offers a wonderful case, showing how an evolutionary and systems perspective is necessarily broken out, to liberalize our cognitive capacity in front of explosive complication of the subject in study. In terms of NIS analysis, we need a framework like this in the first place, for collective efforts to be made in a communicable manner. Otherwise NIS would in the developing world be only a topic of a few researchers in their ivory tower, its value would shrink rapidly not only in policy terms, but also academically.

NIS in Developing countries

Accordingly, a NIS in a developing country has to be analyzed as having its roots deeply embedded in economic and societal structure of the developing country, which, in the Fei and Ranis framework, is experiencing a historical transition. A major contribution of NIS in developing countries, like that in OECD countries, may be expected to be interpreting and hence supporting for policy making, aiming to promote productivity gains from Kutznets or Schumpeter type which concerns science and technology involved innovation. Increasing productivity gains from the type are essentially realized in the context of structural and institutional development, which expands and deepens division of labor in a developing country through a long and heterogeneous process of catching up. Owing to the profound historical transition nature of economic development, distinctive characteristics of NIS in developing countries need to be identified. Following are a primitive sketch in general level, a more detailed development will be made in the next section.

1, *NIS in developing countries are less developed by order*, in terms of institutional composition, the sophistication of scientific and technological activities, and linkages between organizational units. This is because historically the technological and institutional attributes required for modern growth were not developed within their systems. Industrialization implies fundamental transformation of these traditional

systems to be innovative and dynamic. For NIS in developing countries, merely informing the current lower levels of their systems like the OECD project reports (OECD 1999b: 30), gives less information.¹² More important is asking how did innovation related activities start, and how they continued to improve once started, in linking with their local conditions and changing relationship with international and domestic sources, namely, asking *the institutionalization process of NIS in the context of economic development*. By the same token, a broad definition for a NIS survey may be more desired for a developing country which puts firms in the center with their knowledge links going to both domestic and international suppliers and supporters. A narrow definition means a focus on formal and public R&D institutions, which may result in a picture rather partial since formal R&D has a less direct role during catching up (Fagerberg 1987) as far as industrial innovation systems are centrally concerned. Agricultural R&D and extension systems are often more publicly organized and invested, and should not be mixed up with industrial systems.

2, NIS in developing countries are *development sub-phase or development-level specific*. This is a natural derivation from the heterogeneous historical transition in which institutional structure and the ability of an economy in raising productivity gains from modern sources change over time.

Indicators referring to development level such as per capital income and productivity level have been conventionally used in the catching up literature (Abramovitz 1986; Maddison 1991; Fagerberg 1987). These are outcomes from empirical accounting, still meaningful when a uniformed general equilibrium is conceptually substituted by an evolutionary framework. In addition to the conventional quantitative indicators, a second kind of indicators are necessarily to introduce, relating to structural and institutional development in a developing economy (Fei and Ranis 1997: 371), describing structural and institutional development level, or, level of 'organized complexity' in their systems evolution. Sectoral structure, financial institution, and the relative role of government are applied by Fei and Ranis. In relation to technological innovation which compound the sources for Kutznets or Schumpeter type productivity gains, educational, scientific and technological institutions, knowledge links of firms, clusters, networks, science and technology policy institution are important factors, the

¹² But note again that the Catching-up Group is not the major part of the project reported in (OECD 1999b).

OECD NIS project has provided excellent illustration. For developing countries, perhaps important is to link NIS development level with economic structural and institutional development level.

NIS are not only development level specific, but also *country-specific*, meaning that two developing countries with similar initial conditions and development performances, the patterns of their NIS differ in terms of institutional structure, scientific strength and technological and trade specialization, as has been highlighted in the OECD NIS survey, but not acknowledged in the Fei and Ranis framework. Country specific patterns imply that a development path is unique to a particular national innovation system. We will return to this issue in Section 5.

Having had these indicators as above mentioned, how to define sub-phases of a development process is still not clear. Fei and Ranis attempt to find a generally applicable definition for sub-phases by analyzing Taiwan. But it is better to keep this issue open, subject to more empirical evidence. Fei and Ranis also suggest to develop a basic ‘uniqueness typology’ in order to generalize lessons from individual studies, along with the terms of ‘economic-geographical variety’ and the ‘historical-cultural variety’ (Fei and Ranis 1997: 375, 380). This suggestion is useful, but needs to be added the note that it is an open-end schedule, preserving enough space for ever richer evidence in typological terms and in country specific details. There is always a nice desire that the ‘best’ practice (or a good practice) in development policy can be transferred quickly to the remainders. However the county-specific nature of NIS warns us to be very careful with straightforward borrowing.

3, Would a transition growth--suppose most of developing countries have entered in the track of a transition growth--automatically bring about successful catching up to every developing country? The divergent and frustrated experience of catching up deny the possibility. Studies on the ‘exceptional’ success in South Korea and Taiwan show that rapid learning and technological innovation through imitation that increased the marginal productivity have served a driving force there. These latecomers climbed the learning ladder fast, mastering increasingly sophisticated technological and managerial skills, and thereby narrowed the gaps significantly with the world’s industrial leaders in the space of thirty to forty years. (Nelson and Pack 1995; Dahlman and Nelson 1993; Hobday 1995; Kim 1997; Stiglitz 1996, among others). *Extraordinary ‘enhanced learning’ is the key for a successful catching up which requires and is supported by a rapid development of their NIS.* Fei and Ranis might have been over optimistic by commenting that ‘the contemporary Third World is indeed engaged in a successful transition

effort' (Fei and Ranis 1997: 44-45) without indicating the necessary condition of purposeful and intensive learning involved in a success. We need to remember historical lessons. There have been various kinds of 'low equilibrium' traps associated with low learning, such as the centrally planned economies (Kornai 1980), and the merely trade pushed regimes (Lewis 1978, for the last century's Latin America). None of them has led to a successful transition.

Enhanced learning is a result of actively adaptive strategy at both national and firm levels. The role of governmental policy is better analyzed in the strategic management of transformation of a national economy, and therein, a national innovation system (e.g. Mathews 1999), with the expectation to achieve ever higher performance towards that demonstrated by advanced economies (demonstration effect). The NIS perspective acknowledges the importance of adaptive behavior of both firms and policy makers in general. While in analyzing a developing NIS, *purposeful strategic management for catching up* is a factor of higher importance, compared with OECD countries.

4, The role of market in promoting learning and generating change needs to receive special attention.

A systemic view of NIS has been complementary for rather than contradictory to the roles of both government and market, which has released an analyst from an awkward dichotomy of either market or government. It would be wrong if suppose that NIS overlooks the role of market. Earlier we explained that the NIS perspective focuses on change in contrast to the general equilibrium view of market. But the perfectly competitive market at general equilibrium is more a matter of theoretical abstraction. As Metcalfe points out (1998:10), 'A theory (about market) which is designed to illuminate the allocation of given resources to given ends will be thoroughly different in character from one which is designed to explore the nature of economic development and the creation of resources and opportunities (upon market) over time' (words in parentheses added). Market economic regimes are the most effective among practiced economic regimes of the modern time in generating change and achieving high performance of development. Market regimes equip decentralized decision-making structure, embody more efficient information gathering and distributing channels, and offer higher incentive and selection mechanisms. Policy recommendations advised for OECD countries (OECD 1999b), many of which are related to public and collective actions, may offer inadequate reference on the role of market for developing countries, where market mechanisms are still under-developed. Surely promoting the development of

market mechanisms should be an important part of government policy in developing countries. It is also worth noting to avoid a misinterpretation of these OECD policy recommendations, by someone if he still takes an old fashioned interventionist bias of pre-market reform time in developing countries.

5, For developing countries, *learning to innovate is more closely related to capital investment.*

The importance of knowledge and learning which is centrally concerned by NIS, is rather self-evident for developed economies where the contribution of ‘technical progress’ to growth has been overwhelmingly large according to the results of growth accounting. The role of knowledge and learning is not that straightforward for developing countries. Accounted in the same way, capital investment instead assumes the most important source for growth (e.g. Lau 1996, for Asian NIEs). Krugman (1994) therefore warned that the Asian Miracle economies might come to a halt. On the other hand Hayami (1997) finds that, by comparing Japan (1888-1990) with the U.S. (1800-1989) (also Abramowitz 1993), the basic growth trends of Japan experienced a fundamental change, from that in which capital accumulation contributed the major part like the current developing countries, to that in which Total Factor Productivity (TFP, a proxy to productivity gain after derived the contribution by increased capital to labor ratio) acquires increasing importance, like other modern economies. While it seems that there was such a transformation for the U.S economy too, the transformation in Japan was coming out much slower, some feature of the earlier pattern has been apparently mixed with the latter pattern well into the post-W.W.II time. This may be linked with the fact that capital investment is the necessary means by which a late industrializer acquires technology embodied in capital goods from abroad. The key question then turns to be how effectively a developing economy learns to be innovative with capital accumulation, in order to gradually transform itself towards relying on a modern pattern growth in which ‘intangible’ human capital compared with physical capital creates the major part of wealth.

Growth accounting may provide useful indication to the basic trends and character of growth at aggregate levels, though it does not logically offer the explanation why structural change happens (Pasinetti 1993), or whether capital accumulation results in technical progress or the reverse (Abramowitz 1993). But the indication does give guidance as to where we need to concentrate our attention for detailed microeconomic analysis of learning and intangible assets accumulation, and link it with capital investment and structural change. Fei and Ranis call their framework a combination of classic and neo-classic approaches (Fei and Ranis 1997: 44). In fact, it is a revival and renewal of classic theoretic growth view together with neo-classic production function based growth accounting. The latter is applied mainly as analytic tools.

Our focus is on industrial productivity gains from technology and innovation. For developing countries, a short note regarding agricultural productivity has to be added. For a long time industrial development has conventionally overwhelmingly been emphasized, with agriculture receiving much less attention, this is a wrong interpretation of industrialization. Partly because the agricultural problem was not that serious in the dynamically convergent groups where agricultural productivity growth has been able to proceed hand in hand with industrial development, even in some cases like in England, agricultural revolution pioneered industrial revolution. The problem has been that agricultural sectors in developing countries have to experience a transformation from traditional techniques based to modern science and technology based, for lifting the pressure of explosive population growth, improving living standard of farmers, and providing food crops and industrial inputs in pace with industrial development. Compared with industrial sectors, the transformation of agriculture may be relying less on imported technology because agricultural technology is rather local condition-specific, and because agricultural institutions are deeply inherited from local traditions. In many developing countries, a stagnation of agricultural productivity growth has caused farming and environmental devastation, industrial development is therefore set back sooner or later. This is a big issue related to science and technology policy in all developing countries. The experience in Japan is also useful to draw on, Hayami and Ruttan (1985) among others have made an instructive analysis.

5. LEARNING, INNOVATION, AND CO-EVOLUTION BETWEEN TECHNOLOGY AND INSTITUTIONS IN DEVELOPING COUNTRIES--AN ILLUSTRATIVE RESEARCH FRAMEWORK

Now we are better prepared to look at the substantial issues a NIS survey needs to cover in the context of developing countries, regarding learning and innovation, and the co-evolutionary development of institutions and technology. A proposition has been reached that NIS in developing countries are less developed by order, they are in historical transition, hence NIS there are to be analyzed in a way which is sensible to development level, also sensible to specific backgrounds of individual countries. The institutional development and the role of policy in strategic management of catching up are recognized requiring particular attention. We have also identified a linking point of S&T policy with economic development, that is productivity gains from intangible human capital and modern scientific and technological knowledge that should play an increasing role if a historical transition proceeds successfully. We searched eagerly for and are excited with progresses in the mainstream development economics, where the general equilibrium deadlock is possibly broken up. We are therefore inspired to expect that communication and accumulation on NIS studies will be extended broadly in developing countries as well.

Roughly in correspondence to the OECD NIS survey schedule (see Section 1), we now turn to develop an illustrative framework for NIS survey in the context of developing countries. It is organized under four titles. The first concerns *Knowledge Globalization and Technological Opportunities*, because developing countries have to rely heavily on foreign technology as the source of learning in a long period of catching up. A review of the widely accepted theory of technology life cycle finds that late entry of an industrial follower into mature technology can not be satisfactorily explained. Recent progress indicates that institutions for cross-boarder knowledge diffusion, including international engineering specialists and various forms of international knowledge flows deserve a special attention. The second title concerns *Latecomer Firms and Enhanced Learning*. As the major actor of technological innovation, the NIS approach sees firms the most important part of micro-foundations for the innovation performance of an economy. But firms in developing countries have been very little studied. In a way, firms in developing countries may be analyzed as in the accumulation process of firm-specific knowledge through imitating imported technology. That process should transform an inexperienced latecomer firm into an experienced innovative firm, if it learns extremely intensively.

The third title is *Co-evolution between Technology and Institutions*, under which we only touch upon a few selective aspects and restrict it to a comparative review between Korea and Taiwan. The following aspects are selected: interplay of an innovation system with international knowledge inflows, network effects, FDI and the cluster promotion impact, selected technological strengths, and the role of technological infrastructure. As discussed earlier, co-evolution drives systems moving in specific patterns. The two systems of South Korea and Taiwan, though rather comparable in macroeconomic terms, are quite different in institutional structure, technological strength, and development path, to which we were rather blind before. The fourth *Adaptive Policy Process and the Management of Historical Transition* deals with policy learning and policy innovation, rather than policy measures per se, in the context of developing countries. It is believed that the NIS approach and its underpinning evolutionary perspective should be first and foremost serving as an instrument for our thinking about policy. Policy is, by so doing, released from being as a deterministic factor. Any piece of policy should not be regarded as fixed and universally applicable. In contrast, policy is country-specific. A workable policy runs an adaptive process in interactions with the system to which it aims to introduce a change. Adjustment over time with the operation of the system gives the possibility to the policy process to get system-fitness, that is definitely needed in the management of historical transition in economic development.

The framework and the issues embraced are only illustrative. But the orientation of dealing with the issues is for sure in line with the NIS approach. As one may see, many issues touched upon here have been scantily studied in the contexts of individual developing countries, which however are indisputably needed for a NIS policy to have a knowledge basis. We hope, and this is the purpose of the section, that this tentative and partial effort may invite the attention of researchers from developing countries, to work hard in the development of necessary basic understanding of their particular systems, for effectively applying the innovative approach of NIS into the contexts.

Knowledge Globalization and Technological Opportunities

Knowledge globalization. Although low wage and well-educated labour force are only sources for late industrialization, opportunities for late industrializer to acquire foreign technology are evolved abundant, more plural in the forms in which knowledge is codified or expressed, and more accessible through trade and non-traded channels. Knowledge globalization (Ostry and Nelson 1995) has a lot to do with the fact that knowledge becomes more ‘migratory’ (Badaracco 1991) because of codification. This means that technological knowledge which is initially possessed by its innovator, gets separated from its origin to be movable, taking the forms (Schnaars 1994) such as ‘embodied’ in physical outputs, documented in technical writings

(patents, blueprints, standards, production instructions, user manuals, and advertisements), and generalized in engineering science publications and textbooks. The widespread adoption of engineering education across national boundaries that teaches engineering knowledge to young graduates in developing economies, the trade expansion and the international reallocation of production that facilitates the wide accessibility of technological knowledge of various forms, all have contributed to so called knowledge globalization. However, such an over-optimistic picture needs qualification. What part of technological knowledge is codified better and more readily for dissemination and what is not? What barriers might have developed with the codification of knowledge that tend to impede entry by a late industrializer?

The late entry puzzle and institutions for knowledge diffusion. It is useful in this regard to have a close review of the theory of technology (or industry that the technology in question underpins) life cycle, a theory that has received broad acceptance, applied as a theoretical foundation in a number of related disciplines. In the language of knowledge codification, a technology is 'fluid'--greatly uncertain and least codified--in the early stages, and becomes fairly well codified as it passes on to the 'mature' stages of development. But in the late stages as the theory points out, capital is highly intensively amassed, and related organization of firm which has survived with the rivalry at earlier stages, becomes very large and specialized. The large, complex and specialized firm organization may also be seen as a codification of organizational and managerial knowledge which developed during the life cycle, to better fit the technology in question. With all the capital intensity and organizational complexity, entry barriers to a latecomer rise enormously. The theory therefore predicts that a late entry leads to a less possibility in success, and prefers to recommend for firms to compete in the frontier of technological innovation, namely, taking the advantages of 'first mover'. Late entry, the only way possible for latecomer firms and which has led to successful catching up, is a puzzle from the viewpoint of the theory (Utterback 1996).¹³ Although Vernon (1966), by applying a similar notion of product life cycle to analyze the international reallocation of production, had observed that the production of mature products tends to be moved to low wage abroad, his analysis however was made in regard to the decision by multinational companies, i.e., by the original innovators themselves.

Recent empirical observations (e.g. Klepper 1997; Framzman 1998) on firms structure (industrial ecology) show that there are many industrial branches that do not fill the theory well, though many others do. In the former cases, 'shakeout', a process that is predicted by the theory to be appearing in the late stages of a cycle and results in a fewer incumbents of a mature industry, does not happen. Late entrants in these cases tend to be the survivors, or, the first mover's advantages have disappeared considerably there. It is explained that market structure

(i.e., niche market of a technology which contains many diversified products), the existence of equipment specialists, engineering specialists and software specialists, or simply, engineering specialists, helped the lowering of entry barriers, and facilitated the international diffusion of technology. The pattern of entry, and the configuration of firms structure hence changed as well. These findings are an important complement to the theory of technology life cycle. We assume that they should have even more significant implications for entry, firms structure, learning and innovation through imitation in the context of catching up by developing countries. More generally, it indicates the importance to study on institutions that support cross-boarder knowledge diffusion. Following we exemplify two themes that warrant further study.

- a) The structure of international knowledge flows and the role of multinational company (MNCs). Conventional research agenda has overwhelmingly focused on foreign direct investment (FDI), assumed MNCs the major vehicle of international transfer of knowledge. This focus is too partial to yield useful insights regarding the process in which an industrial latecomer acquires technology effectively. 'Informal' channels such as specialist engineering services, the recruitment of foreign experts, and the great efforts which have been taken by South Korea and Taiwan involving massive inputs of abroad educated national scientific and engineering personnel, must be included and reviewed in relation to formal channels such as FDI and technological licensing. Firms strategy, supporting institutions and government policy are also important. The relative ignorance of many non-FDI factors in this research seems to have been heavily influenced by the standpoint of multinational companies.
- b) The importance of engineering specialists and small high-tech entry. Conventional research gives no discretion to the role of international engineering specialists, which however should be one of the critical components, supportive to late entry, especially small high-tech entry. The presence of international engineering specialists as well as a well developed domestic technological infrastructure may have been critical for successful small high-tech entry in Taiwan (see below). Wong (1999) observes the growth of small 'process' specialist firms in Singapore. They are co-existing with MNCs, providing increasingly sophisticated parts and components manufacturing, engineering and marketing services, backed by active policy promotion. Both 'old' (e.g. Gerschenkron 1962) and 'new' (e.g. Amsden 1989) developmentalists tended to prefer for large-scale entry with heavy involvement of public funding. Successful small high-tech entry may offer strong evidence to redress some aspects of the issue of strategic management of late entry. Relevant is also to ask how international engineering

¹³ He is puzzled about the successful late entry of Japanese firms (Utterback 1996: 47-48).

specialists work in an interactive way with domestic engineering capabilities for the deepening of the NIS in a developing country. Because in advanced economies, various engineering specialists, including the machinery and information and communication industries which are well known as engineering industries, function as important centers for the creation and dissemination of innovation. It is reasonable to assume that a late industrializing economy would never reach the place where it is able to fully economize its investment upon local endowments for local needs if it does not develop such engineering capability and institutions.

Latecomer Firms and Enhanced Learning

Knowledge structure of latecomer firms. There are different perspectives to look at a firm: a production function, a structure of governance and internal contracts, and a house of knowledge creation. In traditional development studies, firms are treated as passive producers of material outputs with a technology determined by capital to labor ratio. In NIS analysis, firms are analyzed dynamically, learning and innovation at firms are assumed to constitute the most important part of the micro-foundations of growth performance of the economy. To the question what characterizes a latecomer firm in learning and innovation, the perspective of firm's knowledge structure is pertinent. Following Pavitt (1998), the knowledge a firm possesses can be distinguished into several types: a) the general understanding of technological knowledge; b) firm specific knowledge, which includes technical knowledge and organizational knowledge. Firm-specific technical knowledge refers to the knowledge that provides the means assisting the development and production of new products and services. Firm-specific organizational knowledge refers to the knowledge that is used for supporting decision making and the management of organizational transformation, to fit the firm better with the development of firm-specific products and services; and c) artifacts, or the products and services as the physical outcome from firm-specific knowledge. Apparently, the strengths of a firm rest on firm-specific knowledge, that is a result of purposed efforts in creating competitive 'artifacts' by applying general and specific technical and organizational knowledge. A developing firm, because of its inexperience in innovation, differs itself from an innovative firm most prominently in the lack of firm specific knowledge. How does a developing firm improve itself? The general understanding of knowledge, among the three types, can presumably be introduced quicker through the recruitment of engineering graduates, but their experience has to be developed and integrated in firm-specific knowledge creation activities. Besides, artifacts can be borrowed and produced locally, but do not serve as a substitute of the ability in generating firm-specific

competitive strengths. Enhanced learning is indispensable in order to turn an inexperienced firm into innovative.

Enhanced learning at latecomer firms. A major difficulty in studying learning process is a serious lack of analytical framework. Individual learning, which can be studied by drawing largely on insights developed in the discipline of cognitive psychology, is useful but inadequate. Learning in the economic sense is essentially a social process, to be analyzed from an organizational and collective viewpoint. We turn to organizational science seeking for useful, though scattered, insights. Nonaka and his colleague's work (Nonaka and Takeuchi 1995) among recent developments is interesting. Kim (1997) goes a similar direction, empirically relying on the experience in South Korea. Drawing on their and others work, several elements can be outlined for further development:

- a) Inputs. Well-educated engineers and managers though inexperienced initially, are the internal principal player of the learning firm. In-house R&D is necessary later on. Mature technology is the major source from outside assisted by many other knowledge flows. The combination between internal and external sources is crucial, and changing over time.
- b) Outputs. End material products are not enough for measuring learning results. The way in which a latecomer firm makes use of technology to produce end products is more relevant. Hobday (1995) takes an OEM (original equipment manufacturing) to ODM (own design manufacturing) to OBM (own brand manufacturing) sequence, to approximately indicate the upward moving of technology mastery by a latecomer firm in the context of export-oriented production. Probably the ability of product or process diversification offers an indication (Scherer 1992), shows that the firm has accumulated considerably a firm-specific knowledge basis. With this basis the firm becomes able to enjoy a Schumpeterian innovation rent upon innovative product or process diversification.
- c) Learning mechanisms. The notion of interactions between tacit and codified forms of knowledge (Nonaka and Takeuchi 1995) is instructive. Analysis on such interactions needs detailed information at the firm level that is seriously little documented. The strategy taken by the firm seems central to the setup of an 'ontological' context for organizational learning that links up learning and capital investment. The portfolios of capital investment determine the intensity of learning and its subject. Analysis on learning mechanisms may also inform details about the nature and role played by human capital inputs. Active firm strategy seems to be a necessary condition to

transform the firm towards more capable. Economic environment is critical to induce actively learning firms to emerge.

- d) Organization and management of firm. There must be unique features in the organization and management of a developing firm to cope with enhanced learning, which is least available in literature. Thinner layers of hierarchical structure and task team organization which offers a feasibility for frequent entry and upgrading are two aspects, mentioned in the context of Japanese and Korean systems.
- e) Discontinuity in the acquisition of technology. An upward sequence in the acquisition of technology is widely observed, such as the move from OEM to OBM as just mentioned, and from implementation (of borrowed technology) to improvement (of the technology) to creation (of own technology) (Kim 1997; Kim and Dahlman 1992). A close review of learning activities involved in such sequence reveals that they require different kinds of key competence. Competence acquired at lower imitative stages is insufficient for moving up to higher stages. This discontinuity is different from what Anderson and Tushman (1990) described discontinuity, which concerns a discontinuity in the configuration of end product and fixed capital, appearing in the context of competing at the frontier of technology. Presumably, frequent and formidable fluctuations and disruptions associated with late industrialization have a root in the discontinuous nature of imitative learning. Starting to assemble mature products is not a difficult job in the time of knowledge globalization. Assembling mature products however does not automatically improve the competence necessary for the development of firm-specific design. The essay of static comparative advantage offers nothing but misleading in this regard.

Co-evolution Between Technology and Institutions--A Comparative Review of NIS in South Korea and Taiwan

Interplay with international knowledge inflows. With international knowledge being the most important external resources for late industrialization, interplay between knowledge inflows and a national innovation system can be fairly a focusing point of analysis. The institutional characteristics of national innovation systems help to highlight how the 'social adaptive ability' (Abramovitz 1986, 1989) or 'national absorptive capacity' (Mowery and Oxley 1995) are institutionalized and functioned differently in different national systems.

A preliminary review shows that there are considerable distinctions between Korea and Taiwan, although statistical data from different sources are not well comparable. In terms of knowledge inflows, licensing has been the most important channel for Korea, while for Taiwan, FDI and

licensing have been equally important, played roles in a complementary way. For example, FDI composed between 0.6 % and 2.3 % of gross capital formation in Korea during 1962 to 1990, with 1972-1976 being the peak years (Sakong 1993: 117). In Taiwan, the percentage of FDI invested in manufacturing was on average 7.9 % for 1973-1979 (Clark 1989: 184).

On the other hand, firms structures differ significantly between the two systems in Korea and Taiwan. Measured by the concentration degree of firms, the Korean system has developed remarkably more centralized firms structure than Taiwan does. Statistics demonstrate that except intermediate product sectors in which the two systems are similarly high in concentration levels, all other sectors with only few exceptions see Taiwan having much more decentralized structure. A comparison of firms structure in 'engineering' sectors shows as follows. In the industrial machinery sector, 50 largest *Cheabols* make up 34.9 % of total sales in Korea, in comparison, 96 largest business groups account for 9.8 % of total sale in Taiwan. Other several pairs of the percentage are: 50.9 % for Korea to 22.7 % for Taiwan in the electronic products sector, 79 % for Korea to 39 % for Taiwan in the transportation equipment sector, and 14% for Korea to nil for Taiwan in the precision instruments sector.¹⁴ Presumably, causal relations between the structure of knowledge inflows and firms structure is high, given that other conditions are roughly equal for the two systems, including a strategically active government, a strong out-looking development approach, and certain degree of pre-war development.

Network effects. The distinctions between Korea and Taiwan suggest the relevance to give an emphasis on the effects of networks. For our purpose, networks may be simply and fundamentally understood as the attributes of market, from the proposition (Johanson and Mattsson 1987) that 'industrial markets are characterized by lasting relationships among firms. Networks are the bearing of various kinds of lasting relationships among producers, users, suppliers, and competitors at the marketplace. Firms operate upon networks to cope with technological inter-relatedness, develop specialization, and innovate at lower cost and with higher flexibility. Enhanced learning is reviewed in the above within the territories of individual firms, that is approximately the case of the Korean system. Enhanced learning is also possible to take place in small firms under strong network support. Knowledge about network effects is pertinent for policies with the aim at 'market augmenting' (Amsden 1989; Teubal 1998) as well as late entry, these are goals intrinsically associated with economic development in developing countries.

Evidence in Taiwan and Korea comparison shows that various kinds of networks are developed including trading networks (Egan and Mody 1992; Levy 1991), parts and components supplier-user networks which are usually described as sub-contracting networks (Ernst 1998; Levy and

Kuo 1991; Schive 1978), classmate and professional ‘peer’ networks (Ernst 1998), and networks between academics, technological infrastructure and their industrial users (Hobday 1995; Ernst 1998; Chiang 1990). Networks are penetrating, some are internationally penetrating such as trading networks, subcontracting networks and ‘peer’ networks, serving as channels for flowing technological knowledge and marketing information across national borders. In the circumstances of active catching up, these networks seem to be in rapid expansion and improvement. They are themselves knowledge-intensive and entrepreneurship-intensive. Such networks are part of the invaluable assets of a national innovation system for successful catching up.

FDI and the cluster promotion impact. It is useful, following Dunning (1993: 102-127) and Porter (1990), to identify ‘cluster promoting’ FDI, in order to explore systems impact on interplay with international knowledge inflows. It seems that to which extent a promoting role FDI can play is largely a function of the host system, less that of foreign investors, though there are behavioral variation observed among different sources of FDI.

The FDI-friendly environment in Taiwan embraces, according to our tentative survey, at least three elements: a) industry policies that are neutral, i.e., non-discriminative to small entry; b) policies that encourage FDI while keeping discretionary guidance towards the ‘linkage effects’ with a clear target to integrate FDI with local economic development; and c) the existence and expansion of small manufactures. These three elements reinforce each other dynamically. The existence of specialized local suppliers of components, systems, and engineering services is a necessary condition (Teece 1996) for attracting higher technology-involved FDI with the potential in greater economies of scope contained in the local market. However, local parts producers were not so specialized and experienced initially. Training, standardization and other technical and managerial supports then have been massively provided and promoted by local government in which efforts by FDI are often incorporated, driven by their own interest, as well as by local policy co-ordination. Continuous entry, opened by relatively neutral policy, expands and improves the pool of local suppliers and producers, of whom remarkably are small scale high-tech entrants, spun from various infrastructure units (Hou and Gee 1993; Hobday 1995). They have been playing an important role in the upgrading of the industrial structure, and the extension and deepening of the market networks of the system. In summary, each arrival of foreign technology sponsors learning to take place simultaneously in many loci of the networks, forward and backward, and the accumulations of previous learning is attainable for further waves of such learning under the strong network effects. FDI in Taiwan, being closer integrated in the local system, is not only cluster-promoting, but also a learning-catalyst spreading

¹⁴ Juana Kuramoto, INTECH mimeo 1998, reproduced from the data in Working Paper No. 5887, National Bureau of Economic Research, Washington D.C.

knowledge and learning around networks, a role which is less observed in the Korean system played by either FDI or local *Cheabols*.

Selected technological strengths. It seems that in industrial leaders, especially in the United States, firms structure and technological strengths are largely an outcome of a natural process which emerge, grow, mature, and extinguish following life cycles of technology, latecomer firms are positioned very differently. In late industrializing economies incumbent firms (Nelson 1998) make the choice of technology. Technologies chosen tend to be conditioned heavily by firms size and their external network linkages where the kinds of resources to meet with the chosen technology are accommodated. This leads to the necessary distinction between mass production technology and niche and flexible technology. South Korea, in correspondence to its concentrated firms structure, developed mass products such as cars and general purpose ICs (e.g. DRAM), typically competitive in the international market. Taiwan in contrast characteristically developed niche products such as simpler CNC machine tools and computer peripheries as internationally comparative. Because the accumulation of technological strength is path-dependent, an important choice of technology earlier gives the way to which the consequent choices have to follow. Any radical shift of the trajectory would be costly. With the lock-in effect of established trajectories, Korean firms for instance have become accustomed in choosing technology involving higher economies of scale realized through mass production (e.g., Suh 1997). Questions that follow to deserve an attention include: what strengths and weaknesses are involved in mass production technology? And what are involved in niche and flexible technology? And, in order to learn lessons, what factors caused the different firms structures in the two cases of South Korea and Taiwan?

The role of technological infrastructure. The fact that industrial latecomers have to borrow foreign technology heavily has flustered the understanding with respect to what role the domestic scientific and technological infrastructure plays in catching up. In industrially developed countries, a two-way relationship between science and technology has evolved out of centuries' development, with science growing on its own logic, and in the meanwhile largely being induced by newly emerged technological problems of industry which often have little scientific understanding at the beginning. The two-way relationship has hence put a scientific ground for industrial development in the developed world for a long time (Rosenberg 1982; Nelson and Rosenberg 1993). There is a large range of institutions developed to support the two-way relationship, on the top and the most visible are universities, public R&D laboratories, academies, and technological extension stations, together with many less formal but equally important links and associations. Formal R&D are the major subject of conventional S&T policy (ref. to the policy recommendations by UNESCO), and standard R&D statistics. Standard statistics on R&D may serve an approximation to the intensity of innovation possibility

generation where linkage mechanisms have been well created. But the standard R&D statistics have very different implications to developing countries where the role of science for innovative activities is in support of borrowing foreign technology. With a simplistic view of R&D, two kinds of biases exist simultaneously in the spheres of science and technology policy in developing countries: that which is proponent for higher R&D, and that which is opponent and underestimates the importance of science and R&D. Pragmatically, the opinion which dominates the policy-making agenda tends to switch from one end to the other, and the development of a healthy scientific and technological infrastructure has been inflicted in many cases. Indeed, the role of science and R&D for catching up has long been in controversy upon segmented evidence and partial conceptions.

Illustrated by the recent trends in OECD countries, the perspective of NIS may be useful to redress the old dilemma. Putting the issue in the context of historical transition, the development of a scientific and technological infrastructure is to be managed by combining short term economic returns from serving for technological borrowing, and long term health of a scientific and technological basis needed for a modern society. As far as supporting firms acquisition of technology is concerned, the perspective of NIS tends to ask questions regarding institutions and linkages with firms. The systems in Korea and Taiwan developed differentiated institutions and linkages with firms, although both have since the 1980s turned to rapidly increasing investment in science and R&D. In terms of government financing of R&D, Korea has the lowest record of 19% (for 1995, OECD 1999b: 31) even compared with advanced OECD economies. In contrast, this figure for Taiwan is slightly lower than 50%. In Korea, R&D have been greatly incorporated into a small number of big firms, the role of R&D is also internalized, which appeared in statistics is of 'private' or 'business' R&D. While having the majority of business firms small and medium sized, the public efforts on R&D and other technological supports have to be carefully developed outside firms in Taiwan. Hence training, standardization service, technological consultation, as well as spin-offs from the public infrastructure which have been important sources for the Taiwan's entry into high-tech ICT, visibly characterize the Taiwan system (e.g. Schive 1978; Hou and Gee 1993). We expect that more will be revealed from the research focus proposed by the NIS approach, as well as that with respect to whether and how a two-way relationship between science and technology is developed in an industrial latecomer system. This should be an indication to the extent in which a developing NIS becomes mature.

Adaptive Policy Process and the Management of Historical Transition

The NIS approach is developed for policy innovation in dealing with change and complexity. It has emphasized country specific patterns of NIS and unique paths in which NIS develop in different contexts. Specific patterns are driven by complicated interactions between technology

and institutions taking place in individual systems, in which elementary actors create change and adapt to change to mitigate tension and disorder accompanied with change. Adaptive systems remember their past, meaning that experiences with change in one interval of time are embodied in the system and thereby the way the system moves on in the next interval of time changes as well. The notion of path-dependency captures the implications that historical event matter, as explained earlier (North 1990; David 1975). Recent work by Aoki and his colleagues (Aoki 1988; Aoki, Kim, and Okuno-Fujiwara (eds.) 1996) contends for the pluralist paths of development even stronger. They insist, based on game theory, that plural states for systems are the norm because various institutional, political, cultural and historical factors differ greatly among economic systems.

The NIS approach also positions a policy maker to be a part of the system, he stands in close interactions with the system which he takes a responsibility to coordinate. Accordingly, the way in which a policy maker plays a role has been explained very differently from conventions. A policy maker is assumed not much freer than a firm manager in making decision. The policy institutions and the status of the system restrict him. He is also not much more competent than a firm innovator. A policy initiative may incur unperceived response just like a firm innovator has to deal with uncertain outcome from his innovative action. With limited ability in knowing and with various restrictions in making decision, a successful policy maker must be adaptive, adjusting a policy with the operation of the system to which the policy is aimed to introduced a social innovation. Following we review the NIS policy approach above described in the context of developing countries.

Country-specific S&T policy. With paths and patterns being country specific, science and technology policy is country specific as well. It is unavoidably bound to a particular NIS (and to specific goals too). It is observed that whilst Korea and Taiwan share similarities in basic orientations in their S&T policy, the emphasis and the major means of their technology policies differ distinctly. In Korea, the priority of technology policy has been given to so-called 'strategic industries' (automobile, shipbuilding, machinery, and microelectronics). Financial, taxation and fiscal measures are intensively used to rather directly promote large *Cheabols* in the procurement of foreign capital goods, paying for licensing fees, and investing in in-house R&D activities (Kim 1988; Kim, Lee and Lee 1987). In Taiwan, a dual or more balanced priority is set up for technology policy. It gives direct intervention and financial support to large-scale, technologically complex upstream sectors, typically intermediate goods sectors. In other sectors the major focus of technology policy has been in securing infrastructure services. Subtle measures are developed to offer technical supports to small and medium firms, and to boost knowledge-spillovers and small high-tech spin-offs, as has mentioned.

With greatly differentiated institutional structures among developing countries, policy measures that fit in one system can not be simply moved to the other. A simplistic comparison in concrete terms of technology policy makes little sense, such as that a higher proportion of industrial R&D is performed in private firms in Korea does not mean that government intervention is less heavier there. The NIS approach, with the view of development path pluralism, rejects that any a single policy package can be universally applicable to different circumstances. It instead advocates for a policy process which keeps the most basic principles, such as promoting knowledge inflows and enhanced learning, creating innovative dynamics, facilitating the development of knowledge networking. Detailed policy measures may be better made only based on intimate analysis of local situations in technology, institution, human capital, and other aspects. And as a process an initiated policy must be open to timely adjustment.

The management of systems transition. The notion of path-dependence also predicts the very difficulties in changing a system. Indeed many authors have noticed the inertia of institutions (North 1990; Johnson 1992), which are essentially reasons for the difficulties involved in systems change. However, the most pressing challenges that industrial followers face are fundamental systems change. To embark on the process of industrialization implies a start of dramatic transformation of conventional institutions. And the process of industrialization is, once started, by no means of linear type, more fundamental changes will follow. For the sake of policy process being able to cope with radical transformations which is more often associated with economic development, knowledge concerning 'path-shifting' under the impact of path-dependence is imperative.

As we have seen in Sections 1 and 2, adaptive policy making has been taken by the NIS approach necessary for managing systems change. Aoki and his associates (Aoki, Kim, and Okuno-Fujiwara (eds.) 1996) drawing similarly on the concept of co-evolution, reason a positive, learning policy process for radical systems transformations involved in economic development. Co-evolution between policy initiatives and reactions made by economic agents, according to them, is indispensable because interrelationship between parts and components of a system is complex and complementary. After a major reform initiative, various institutional components must make adjustments to cope with the initiated disturbance and to re-build complementary relations with each other as well. Such institutional adjustment process takes its own way, with outcomes often not expected initially ('unexpected fit'). It is impossible for a reform programme to be decided perfectly, or even roughly properly in advance. Hence it is an adaptive, learning process that grants the possibility in which a profound change of a system is able to proceed successfully. My own work (Gu 1999) on the transformation of the industrial R&D system in China during the 1980s to 1990s market reform, precisely confirms the critical importance of social-wide mutual learning. Interactions between policy maker and lower levels

of economic performers have been the major sources of information, which is continuously fed back into the policy process for adjustment. In the meanwhile complex fitting and refitting between institutions in terms of their structures, functions and technological activities have been taking place widely that makes the reform initiative adapted and consolidated into the system. Intensive policy learning, institutional learning, and technological learning have been one of the major resources invested into the relatively smooth transition from a centrally planned regime into a market-oriented system. In short, changing the path of a system is not impossible, adaptive policy process with extraordinarily intensive policy learning is an answer from the point of view of NIS.

But questions remain, as with respect to how a reform initiative can be started, and how to keep a policy initiative in a positive learning process. These are open questions, they require much more research effort. It seems that the inertia of institutions tends to deter necessary reform initiatives until a big shock comes to press for change. A development government is inclined to respond to shocks positively, but not always so. Internally, a consensus reached in a society is a necessary condition. Externally, help from international organizations and advanced countries is needed, to play a role of 'a third agent', in assisting an initiative to change (Teubal 1998). This however raises a further question to an external helper as what is best to do and what has to be refrained not to do, provided that reform is intrinsically an internal process. Only through internal co-evolution can a national system pave its way towards tomorrow. The co-evolutionary nature of transformation of a system may have to place local policy makers to be decisive in the international policy arena. Following the instruction of adaptive policy process, the burden of policy making in producing perfect reform projects at once may be reduced. But the requirement for adaptive capacity of local policy making is extremely tightened. To a larger extent, it is the responsive capacity of policy making that is among the most critical factors for the fate of historical transition of a NIS as well as of a developing economy.

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This paper reviews the concept about national innovation systems, and the policy approach devised by the idea of national innovation systems. The message from the review is simple. The notion of national innovation systems is a synthesis made at the national and other societal levels, of the insights about technological innovation and institutional change. Its strong policy orientation came from the need to manage change and complexity for economic growth and development. People in OECD countries are indeed experimenting with the new approach to social innovation seriously. It, without doubt, should be adapted as one of the most relevant policy instruments to developing countries for knowledge based economic development (World Bank 1999).

The new approach to social innovation requires two conditions: the moods of change, and the capacity in generating knowledge for change. It is in the preparation for the conditions that developing countries are lagged far behind. There is no reason for being pessimistic, but every reason for taking action to fill the gaps, provided that the new way has broken through in our advanced neighbors, if we learn hard and smart.

REFERENCES

Abramovitz, 1986

Moses Abramovitz: Catching up, Forging Ahead, and Falling Behind, *The Journal of Economic History*, Vol. 46, No. 2, 1996: 385-406

Abramovitz 1989

Moses Abramovitz: *Thinking About Growth*, Cambridge University Press, Cambridge, New York, Port Chester, Melbourne, Sydney

Abramovitz, 1993

Moses Abramovitz: The Search for the Sources of Growth: Areas of Ignorance, Old and New, *The Journal of Economic History*, Vol. 53, No. 2, 1993: 217-243

Amsden 1989

Alice H. Amsden: *Asia's Next Giant: South Korea and Late Industrialization*, Oxford University Press, New York, Oxford, 1989

Anderson and Tushman 1990

Philip Anderson and Michael Tushman: Technological Discontinuity and Dominant Designs: A Cyclical Model of Technological Change, *Administrative Science Quarterly*, Vol. 35, no. 4 (December 1990) 604-633

Andersson 1998

Thomas Andersson: Managing a Systems Approach to Technology and Innovation Policy, in OECD 1998a: 9-29

Aoki 1988

Masahiko Aoki: Information, Incentives, and Bargaining in the Japanese Economy, Cambridge University Press, Cambridge, New York, Port Chester, Melbourne, Sydney, 1988

Aoki 1996

Masahiko Aoki: Unintended Fit: Organizational Evolution and Government Design of Institutions in Japan, in Aoki, Kim and Okuno-Fujiwara (eds.): *The Role of Government in East Asian Economic Development, Comparative Institutional Analysis*, Clarendon Press, Oxford, 1996: 233-253

Aoki, Kim, and Okuno-Fujiwara (eds.) 1996

Masahiko Aoki, Hyung-ki Kim and Masahiro Okuno-Fujiwara (eds.): *The Role of Government in East Asian Economic Development*, Clarendon Press, Oxford, 1996

Badaracco 1991

Joseph L. Badaracco, Jr.: *The Knowledge Link*, Harvard Business School Press, Boston, Massachusetts, 1991

Baumol 1994

William J. Baumol: Multivariate Growth Patterns: Contagion and Common Forces as Possible Sources of Convergence in Baumol, Nelson and Wolff (eds.) 1994: 62-85

Baumol, Nelson and Wolff (eds.) 1994

William J. Baumol, Richard R. Nelson, Edward N. Wolff (eds.): *Convergence of Productivity, Cross-National Studies and Historical Evidence*, Oxford University Press, Oxford 1994

Behrman and Srinivasan 1995a

Jere Behrman and T.N. Srinivasan: Introduction to Part 8, in Behrman and Srinivasan (eds.): *Handbook of Development Economics*, Elsevier, Amsterdam, Lausanne, New York, Oxford, Shannon, Tokyo, 1995: 2111-2122

Behrman and Srinivasan 1995b

Jere Behrman and T.N. Srinivasan: Introduction to Part 9, in Behrman and Srinivasan (eds.): *Handbook of Development Economics*, Elsevier, Amsterdam, Lausanne, New York, Oxford, Shannon, Tokyo, 1995: 2467-2496

Behrman and Srinivasan (eds.) 1995

Jere Behrman and T.N. Srinivasan (eds.): *Handbook of Development Economics*, Elsevier, Amsterdam, Lausanne, New York, Oxford, Shannon, Tokyo, 1995

Caracostas 1998

P. Caracostas: Towards Systemic Policy at the European Level: Five Key Challenges for the Future, in OECD 1998a: 307-321

Carlsson (ed.) 1997

Bo Carlsson (ed.): *Technological Systems and Industrial Dynamics*, Kluwer Academic Publishers, Boston, Dordrecht, London 1997

Carlsson and Jacobsson 1994

Bo Carlsson and Staffan Jacobsson: Technological Systems and Economic Policy: The Diffusion of Factory Automation in Sweden, *Research Policy*, 23: 235-248

Carlsson and Jacobsson 1997

Bo Carlsson and Staffan Jacobsson: Diversity Creation and Technological Systems: A Technology Policy Perspective, in Edquist (ed.) 1997: 266-294

Chan and Clark 1992

Chan, Steven and Cal Clark: *Flexibility, Foresight, and Fortune in Taiwan's Development, Managing between Scylla & Charysdis*, Routledge, London and New York

Chiang 1990

Chiang, Jong-Tsong: Management of National Technology Programs in a Newly Industrialized Country-Taiwan, *Technovation*, 10:8, 1990: 531-554

Clark 1989

Cal Clark: *Taiwan's Development, Implications for Contending Political Economy Paradigms*, Greenwood Press, New York, Westport, Connecticut London

David 1975

Paul A.David: *Technical Choice, Innovation and Economic Growth*, Cambridge University Press, Cambridge, 1975

David 1985

Paul A.David: Clio and the Economics of QWERTY, *Economic History* 75, 1985: 332-337

David and Foray 1995

Paul David and Dominique Foray: Accessing and Expanding the Science and Technology Knowledge Base, *STI Review*, No. 16, 1995: 13-68

Dosi 1982

Giovanni Dosi: Technological Paradigm and Technological Trajectory, *Research Policy* 11, 1982: 147-162

Dosi, Teece and Chytry (eds.) 1998

Giovanni Dosi, David Teece and Josef Chytry (eds.): *Technology, Organization and Competitiveness, Perspectives on Industrial and Corporate Change*, Oxford University Press, 1998

Dunning 1993

John H. Dunning: *The globalization of business, The challenge of the 1990s*, Routledge, London and New York

Edquist (ed.) 1997

Charles Edquist (ed.): *Systems of Innovation, Technology, Institutions and Organizations*, Pinter, London and Washington, 1997

Edquist and Lundvall 1993

Charles Edquist and Bengt-Åke Lundvall: Comparing the Danish and Swedish Systems of Innovation, in Nelson (ed.) 1993: 265-298

Egan and Mody 1992

Mary Lou Egan and Ashoka Mody: Buyer-Seller Links in Export Development, *World development*, Vol. 20, No. 3, 1992: 321-334,

Enos 1995

J.L.Enos: *In Pursuit of Science and Technology in Sub-Saharan Africa*, Routledge in association with the UNU Press, London and New York, 1995

Ernst 1998

Dieter Ernst: What Permits Small Firms to Compete in High-Tech Industries? Inter-Organizational Knowledge Creation in Taiwanese Computer Industry, *DRUID Working Paper No. 98-3*, Aalborg University, Aalborg, Denmark

Ernst, Ganiatsos and Mytelka 1998

Dieter Ernst, Tom Ganiatsos and Lynn Mytelka: *Technological Capabilities and Export Success in Asia*, Routledge, London and New York

Evenson and Westphal 1995

Robert E. Evenson and Larry E. Westphal: Technological Change and Technology Strategy, in Behrman and Srinivasan (eds.): *Handbook of Development Economics*, 1995: 2209-2299

Fagerberg 1987

Jan Fagerberg: A Technology Gap Approach to Why Growth Rates Differ, *Research Policy* 16, 1987: 87-99

Fagerberg 1995

Jan Fagerberg: Catching Up and Falling Behind in Economic Development, *Journal of Evolutionary Economics*, Vol. 5, issue 3, 1995: 269-284

Fairbanks and Lindsay 1997

Micheal Fairbanks and Stace Lindsay: *Plowing the Sea: Nurturing the Hidden Source of Growth in the Developing World*, Harvard Business School Press, Boston, Massachusetts, 1997

Freeman 1987

Chris Freeman: *Technology Policy and Economic Performance: lessons from Japan*, London, Pinter, 1987

Freeman 1997

Chris Freeman: Innovation Systems: City-State, National, Continental and Sub-National, typescript, SPRU, University of Sussex

Fei and Ranis 1997

John C. Fei and Gustav Ranis: *Growth and Development From an Evolutionary Perspective*, Blackwell Publishers, Malden USA and Oxford UK, 1997

Gerschenkron 1962

Alexander Gerschenkron: *Economic Backwardness in Historical Perspective*, A Book of Essays, The Belknap Press of Harvard University Press, Cambridge, Massachusetts, and London, England, 1962

Gu 1996

Shulin Gu: Toward an Analytical framework for National Innovation Systems, *UNU/INTECH Discussion Paper 1996-4#*, Maastricht, 1996

Gu 1999

Shulin Gu: *China's Industrial Technology, Market Reform and Organizational Change*, Routledge in association with the UNU Press, London and New York, 1999

Hayami 1997

Yujiro Hayami: *Development Economics, from the Poverty to the Wealth of Nations*, Oxford University Press, Oxford, 1997

Hayami and Ruttan 1985

Yujiro Hayami and Vernon W. Ruttan: *Agricultural Development, An International Perspective*, The John Hopkins University Press, Baltimore and London, 1985

Hikino and Amsden 1994

Hikino and Amsden: Staying Behind, Stumbling Back, Sneaking Up, Soaring Ahead: Late Industrialization in Historical Perspective, in Baumol, Nelson and Wolff (eds.) 1994: 285-315

Hobday 1995

Mike Hobday: *Innovation in East Asia, The Challenge to Japan*, Edward Elgar, 1995

Hou and Gee 1993

Chi-Ming Hou and San Gee: National Systems supporting technical advance in industry: The Case of Taiwan, in Richard R. Nelson (ed.): *National Innovation Systems: A comparative analysis*, Oxford University Press, New York and Oxford, 1993: 384-413

Johanson 1992

Bjorn Johanson: Institutional learning, in Bergt-Ake (ed.): *National Systems of Innovation*, London, Pinter, 1992: 23-44

Johanson and Mattsson 1987

Jan Johanson and Lars-Gunnar Mattsson: International Relations in industrial Systems: A Network Approach Compared with the transaction-Cost Approach, *International Studies of Management & organization*, Vol. XVII, No. 1, 1987: 34-48

Kim 1997

Linsu Kim: *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Harvard Business School Press, Boston, Massachusetts, 1997

Kim 1988

Linsu Kim 1988: The Transfer of Programmable Automation Technology to a Rapidly Developing Country: an Initial Assessment, *International Economic Journal*, Vol. 2, No. 2, Summer 1988

Kim and Dahlman 1992

Linsu Kim and Carl J. Dahlman: Technology Policy for Industrialization: An Integrative Framework and Korea's Experience, in *Research Policy*, 21, 1992: 437-452

Kim, Lee and Lee 1987

Linsu Kim, Jangwoo Lee and Jinjoo Lee: Korea's Entry into the Computer Industry and its Acquisition of Technological capability, *Technovation*, 6, 1987: 277-293

Klepper 1997

Steven Klepper: Industry Life Cycles, *Industrial and Corporate Change*, Vol. 6, No. 1, 1996: 145-181

Kline and Rosenberg 1986

Stephen J. Kline and Nathan Rosenberg: An Overview of Innovation, in Ralph Landau and Nathan Rosenberg (eds.): *The Positive Sum Strategy: Harnessing technology for economic growth*, Washington DC, National Academic Press, 1986

- Kogut (ed.) 1993
Bruce Kogut (ed.): *Country Competitiveness, technology and the organizing of work*, Oxford University Press, New York, Oxford, 1993
- Kornai 1980
Janos Kornai: *Economics of Shortage*, North-Holland Publishing Company, 1980
- Kruger 1995
Anne O. Kruger: Policy Lessons from Development Experience Since the Second World War, in Behrman and Srinivasan (eds.): *Handbook of Development Economics*, 1995: 2497-2550
- Krugman 1992
Paul Krugman: Toward a Counter-Counterrevolution in Development Theory, *Proceedings of the World Bank Annual Conference on Development Economics*, World Bank, 1992
- Krugman 1994
Paul Krugman: The Myth of Asia's Miracle, *Foreign Affairs*, Vol. 73, No. 6 (November/December) 1994
- Laszlo 1987
Ervin Laszlo: *Evolution, the Grand Synthesis*, Shambhala Publications, Inc. Boston and London, 1987
- Lau (ed.) 1986
Lawrence J. Lau (ed.): *Models of Development, A Comparative Study of Economic Growth in South Korea and Taiwan*, ICS (Institute for Contemporary Studies), San Francisco, California, 1986
- Lau 1996
Lawrence J. Lau: The sources of long-term Economic Growth: Observations from the experience of Developed and developing Countries, in Landau, Taylor and Wright (eds.): *The Mosaic Economic Growth*, Stanford University Press, Stanford, California 1996
- Levy 1991
Brain Levy: Transaction Costs, the Size of Firms and Industrial Policy, *Journal of Development Economics*, 34, 1991: 151-178
- Levy and Kuo 1991
Brain Levy and Wen-Jeng Kuo: The Strategic Orientation of Firms and the Performance of Korea and Taiwan in Frontier Industries: Lessons from Comparative Case Studies of Keyboard and Personal Computer Assembly, *World Development*, Vol 19, No. 4, 1991: 363-374
- Levy 1991
Brain Levy: Transaction Costs, the Size of Firms and Industrial Policy, *Journal of Development Economics*, 34, 1991: 151-178
- Levy and Kuo 1991
Brain Levy and Wen-Jeng Kuo: The Strategic Orientation of Firms and the Performance of Korea and Taiwan in Frontier Industries: Lessons from Comparative Case Studies of Keyboard and Personal Computer Assembly, *World Development*, Vol 19, No. 4, 1991: 363-374
- Lewis 1978
Lewis, W. Arthur: *Growth and Fluctuations 1870-1913*, George Allen & Unwin, London, Boston, Sydney, 1978
- Lipsey and Carlaw 1998
Richard G. Lipsey and Kenneth Carlaw: Technology Policies in Neo-classical and Structural-Evolutionary Models, in OECD 1998a: 31-73
- Little 1982
Ian M.D. Little: *Economic Development, Theory, Policy, and International Relations*, Basic Books, Inc., New York, 1982

Lundvall (ed.) (1992)

Bengt-Åke Lundvall (ed.): *National Systems of Innovation*, Pinter, London, 1992

Maddison 1991

Angus Maddison: *Dynamic Forces in Capitalist Development, A long-run Comparative View* Oxford University Press, Oxford, New York, 1991

Maddison 1994

Angus Maddison: Explaining the Economic Performance of Nations, 1820-1989, in Baumol, Nelson and Wolff (eds.) 1994: 20-61

Mathews 1999

John A. Mathews: From National Innovation Systems to National Systems of Economic Learning: The Case of Technology Diffusion Management of East Asia, paper submitted to the DRUID Summer Conference *National Innovation Systems, Industrial Dynamics and Innovation Policy*, Rebild, Denmark, June 9-12, 1999

Metcalfe 1995

Stan Metcalfe: The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives, in Paul Stoneman (ed.): *Handbook of the Economics of Innovation and Technological Change*, Blackwell, Oxford UK and Cambridge USA 1995: 409-512

Metcalfe 1998

J. Stanley Metcalfe: *Evolutionary Economics and Creative Destruction*, Routledge, London and New York 1998

Metcalfe and Georghiou 1998

J.S. Metcalfe and L. Georghiou: Equilibrium and Evolutionary Foundations of Technology Policy, in OECD 1998a: 75-136

Mowery 1998

David C Mowery: *Rapporteur's Summary of the Taipei Workshop on "National Innovation Systems in Catching-Up Economies"*, May, 1998, Taipei

Mowery and Oxley 1995

David C. Mowery and Joanne E. Oxley: Inward technology transfer and competitiveness: the role of national innovation systems, *Cambridge Journal of Economics*, 19, 1995: 67-93

Mowery and Rosenberg 1989

David C Mowery and Nathan Rosenberg: *Technology and the Pursuit of Economic Growth*, Cambridge University Press, 1989

Nelson (ed.) 1993

Richard R. Nelson (ed.): *National Innovation Systems: A comparative analysis*, New York and Oxford, Oxford University Press, 1993

Nelson 1994

Richard R Nelson: An Agenda for Formal Growth Theory, *IIASA (International Institute for Applied Systems Analysis) WP-94-85*, Laxenburg, Austria , 1994

Nelson 1995

Richard R Nelson: Recent Evolutionary Theorizing About Economic Growth, *Journal of Economic Literature*, XXXIII, 1995 March: 48-90

Nelson 1998

Richard R Nelson: The Co-evolution of Technology, Industrial Structure, and Supporting Institutions, in Dosi, Teece and Chytry (eds.): *Technology, Organization and Competitiveness*, Oxford University Press: 319-335

Nelson and Rosenberg 1993

Richard R. Nelson and Nathan Rosenberg: Technical Innovation and National Systems, in Richard R. Nelson (ed.): *National Innovation Systems*, Oxford University Press: 3-21

Nelson and Winter (1982)

Richard R. Nelson and Sidney G. Winter: *An Evolutionary Theory of Economic Change*, Cambridge, Mass. and London, The Belknap Press of Harvard University Press, 1982

Nonaka and Takeuchi 1995

Nonaka, Ikujiro and Hirotaka Takeuchi 1995: *The Knowledge Creating Company*, Oxford University Press, New York, Oxford, 1995

North 1990

North, Douglass C. 1990: *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge, 1990

OECD 1991

OECD: *Technology and Productivity, the Challenge for Economic Policy*, OECD, Paris, 1991

OECD 1998a

OECD STI Review No. 22: *Special Issue on "New Rationale and Approaches in Technology and Innovation Policy"*, OECD, Paris, 1998

OECD 1998b

OECD: *Technology, Productivity and Job Creation, Best Policy Practice*, OECD, Paris, 1998

OECD 1999a

OECD: *National Innovation Systems*, http://www.oecd.org/dsti/sti/s_t/index.htm

OECD 1999b

OECD: *Managing National Innovation Systems*, OECD, Paris, 1999

OECD 1999c

OECD: *Boosting Innovation, The Cluster Approach*, OECD, Paris, 1999

Ohkawa and Rosovsky 1973

Kazushi Ohkawa and Henry Rosovsky: *Japanese Economic Growth, Trend Acceleration in the Twentieth Century*, Stanford University Press, Stanford, California, Oxford University Press, London, 1973

Ostry and Nelson 1995

Ostry, Sylvia and Richard R. Nelson: *Techno-Nationalism and Techno-Globalisation, Conflicts and Cooperation*, The Brookings Institution, Washington, D.C.

Pack and Nelson 1995

Howard Pack and Richard Nelson 1995: *The Asian Growth Miracle and Modern Growth Theory*, Manuscript, December 1995

Pack and Westphal 1986

Howard Pack and Larry Westphal: Industrial Strategy and Technological Change, *Journal of Development Economics* 22, 1986: 87-128

Pasinetti 1993

Luigi L. Pasinetti: *Structural Economic Dynamics, A theory of the economic consequences of human learning*, Cambridge University Press, Cambridge, 1993

Pavitt 1998

Keith Pavitt: Technologies, Products & Organization In The Innovation Firm: What Adam Smith Tells Us And Schumpeter Does Not? paper presented at the 1998 DRUID Summer Conference *Competence, Governance, and Entrepreneurship*, 9-11 June, 1998, Bornholm, Denmark

Porter 1990, 1998

Michael Porter: *The Competitive Advantage of Nations*, Macmillan, 1990, 1998 reprinted, The Free Press, New York, London, Toronto, Sydney, Singapore

Rodrik 1995

Dani Rodrik: Trade and Industrial Policy Reform, in Behrman and Srinivasan (eds.): *Handbook of Development Economics*, 1995: 2925-2982

Rosenberg 1982

Nathan Rosenberg: How Exogenous is Science? in Nathan Rosenberg: *Inside the Blackbox: Technology and Economics*, Cambridge University Press, 1982

Rosenberg 1996

Nathan Rosenberg: Uncertainty and Technological Change in Landau, Ralph, Timothy Taylor and Gavin Wright (eds.): *The Mosaic of Economic Growth*, Stanford Univ. Press, Stanford, California, 1996

Rosenberg and Birdzell 1986

Nathan Rosenberg and L.E. Birdzell, Jr.: *How the West Grew Rich, The Economic Transformation of the Industrial World*, N.Y., Basic Books, 1986

Saviotti and Metcalfe 1991

P. Paolo Saviotti and J. Stanley Metcalfe (eds.): *Evolutionary Theories of Economic and Technological Change, Present Status and Future Prospects*, Harwood Academic Publishers, Chur, Reading, Paris, Tokyo, Melbourne, 1991

Scherer, F.M. 1992

F. M. Scherer: *International High-Technology Competition*, Harvard University Press, Cambridge, Massachusetts, London, England 1992

Schive 1978

Chi Schive: *Direct Foreign Investment, Technology Transfer and Linkage Effects, A Case Study of Taiwan*, Ph.D. dissertation, Department of Economics, Case Western Reserve University, 1978

Schnaars 1994

Steven P. Schnaars: *Managing Imitation Strategies, How Late Entrants Seize Markets from Pioneers*, The Free Press, New York 1994

Sen 1991

Amartya Sen: The Concept of Development, in Hollis Chenery and T.N. Srinivasan (eds.): *Handbook of Development Economics*, North Holland, Amsterdam, New York, Oxford, Tokyo, 1991 (Second printing): 9-26

Shin 1994

Jang-sup Shin: *The Economics of the Latecomers, Catching-up, Technology Transfer and Institutions in Germany, Japan and South Korea*, Routledge, London and New York, 1994

Simon 1976

Herbert A. Simon: *Administrative Behavior--A Study of Decision-Making process in Administrative Organization*, Macmillan Publishing Co., 3rd Edition, 1976

Stiglitz 1996

Joseph E. Stiglitz: Some Lessons from the East Asian Miracle, *The World Bank Research Observer*, Vol. 11, No. 2, 1996: 151-177

Suh 1997

Joonghea Suh: Outward Orientation, Technology Transfer and Firm Dynamics: The Case of Korea, a paper presented at Science & Technology Policy Institute, International Symposium *Innovation and Competitiveness in Newly Industrializing Economies*, Seoul Korea, May 26-27, 1997

Teece 1996

David J. Teece: Firm Organization, Industrial Structure, and technological innovation, *Journal of economic behavior & Organization*, Vol. 31, 1996: 193-224

Tuebal 1998

Morris Tuebal: *Enterprise Restructuring and Embeddedness: An Innovation System and Policy Perspective*, typescript, 1998

Veblen 1966

Veblen, Thorstein: *Imperial Germany and the Industrial Revolution*, The University of Michigan Press, 1966

von Bertalanffy 1979

Ludwig von Bertalanffy: *General Theory, Foundations, Development, Application*, George Braziller, New York, 1979 (sixth printing)

Utterback 1996

James M. Utterback: *Managing the Dynamics of Innovation*, Harvard Business School Press, Boston, Massachusetts

Wong 1999

Poh-Kam Wong: National Innovation Systems for Rapid Technological Catching-up: An Analytical Framework and Comparative Analysis of Korea, Taiwan and Singapore, paper presented at the DRUID Summer Conference *National Innovation Systems, Industrial Dynamics and Innovation Policy*, Rebild, Denmark, June 9-12, 1999

World Bank 1993

World Bank: *The Asian Miracle*, Oxford University Press, New York, 1993

World Bank 1999

World Bank: Knowledge for Development, World Development Report 1998/1999, World Bank, 1999

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