Information Revolution and Policy Implications for Developing Countries

--Open Systems, Learning Economies and Development Strategies

Shulin Gu
Visiting Professor, TsingHua University, China
Adjunct Senior Research Fellow, UNU/INTECH
E-mail: shulin008@hotmail.com

Paper presented in the Second UNU Global Seminar - Shimane Session "IT, the Family, and Gender: Coping with Socio-Economic Change in the Information Age", the University of Shimane, Hamada city, Shimane Prefecture, Japan, 24 to 27 July 2001

Abstract

This paper addresses implications of information revolution for developing countries. It takes the perspective of innovation and capability building developed in the schools of innovation studies, attempts to point out some aspects that are of strategic importance in thinking about development in these countries in face of information revolution. Three questions are asked for the purpose.

First, we ask what is happening to OECD countries with the IT revolution? This inquiry leads to an outline of socio-economic transformations in OECD countries towards 'information societies', and emerging mode of technological innovation that is both a cause and an effect of the transformations.

Second, we ask what are opportunities and challenges for developing countries in the global trends moving to information societies? To speak to this inquiry, we analyze technological choices in correspondence to the emerging mode of technological innovation which is characteristic of opening complex systems, networking dynamics, and flexible specialization on the one hand, and factor endowment of developing countries by adding—if they are capable to have it, factors of engineering and institutional capabilities, on the other. The analysis is then reviewed in regard to experiences in some Asian Newly Industrializing Economies (NIEs). This indicates to the necessary emphases on: a, freeing for small entries; b, improving technological infrastructure and supportive institutions; c, human resource development; and d, proactive and adaptive policy-making.

Third, we ask what does development policy with such emphases implicate? To this inquiry, we compare them with conventional thoughts about economic development; the later looks for (physical) capital investment as the solely important factor, gives overwhelming weight on large firms to be the pivotal organizations, and deals with policy-making in the way wavering from one extreme (direct intervention) to the other ('*laissez-faire*'). Although practical adjustments take place in many developing countries, the warning that there is a need for 'paradigm shift' of development policies is pertinent, if developing countries are to cope with changing domestic and international conditions with greater consciousness.

This paper contributes to the idea of knowledge-based development. With the topic being very new and difficult, all the discussions the paper makes are unavoidably primitive.

Content

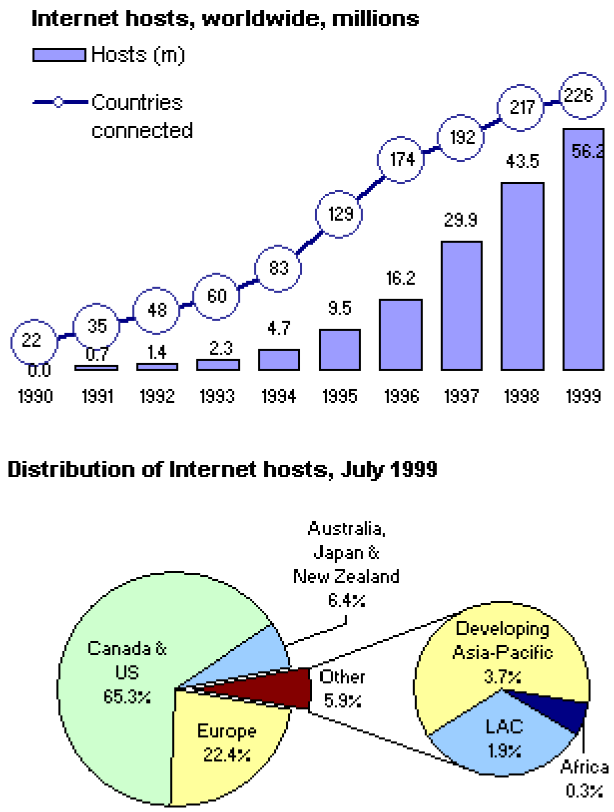
Tables and figures

1, Introduction

This paper addresses implications of information revolution for developing countries. It takes the perspective of innovation and capability building developed in the schools of innovation studies, attempts to point out some aspects that are of strategic importance in managing development in developing countries in face of information revolution.

In quantitative terms, access to personal computer or Internet has in the late 1990s been expanding at an unprecedented pace, although distribution of the access is still uneven. In his speech to the World Telecommunications Day on 17 May 2001, Mr. Harri Holkeri, General Assembly President of the International Telecommunication Union, demonstrates the picture as shown below.

Figure 1: Installed Base of Internet Hosts and Distribution by Region



Note: In the left chart, data refer to January of the following year. A new method was used to calculate Internet hosts from January 1998 onwards. Data were adjusted, based on the new methodology, from January 1995. * LAC = Latin America and the Caribbean.

Source: ITU. Internet host data adapted from Internet Software Consortium <http://www.isc.org > and RIPE < http://www.ripe.net >. Countries connected data sourced from Internet Society.

While for telephone to reach 50 million users it took a time close to 75 years, the World Wide Web (WWW) took only four years to the same number. In 1990, just over twenty countries entered in Internet access, now more than 200 Countries have become Internet connected and altogether Internet users exceed 200 million. By the end of 2000 China has 22 million Internet users that is increased from the much lower number of 1,000 thousand in 1996. Internet access in developing counties including the least developed, in spite of being lagged behind OECD countries, has penetrated to academic institutions, government organizations and big companies.

To address the digital divide issue, this paper takes the angle to quest on opportunities and challenges arising to developing countries in the information age, in relation to the acquisition of technology and improvement in innovation capability. Taking into account the rapid penetration of IT, this is an angle relevant more than ever. It goes beyond merely quantitative access terms. Although necessary to be concerned, the quantitative terms such as extent, content and speed of access would, after an initial introduction, largely be a matter depending on, and motivated by, effective use of the technology for development purpose.

Section 2, titled 'IT Revolution and the Information Societies', reviews briefly the trends in socio-economic transformations with the IT revolution in OECD countries. We need such a review because visions and options that developing countries take to formulate policies cannon be isolated from international developments. This inquiry leads to an outline of 'information societies' that are emerging in these countries. Particularly, the mode of technological innovation, which is both a cause and an effect of the transformations and which shapes the so-called international technological infrastructure, is elaborated.

The next section, Section 3, with the title 'Strategic Choices and Capability Building for Developing Countries: Conventional versus New Approaches', addresses opportunities and challenges for developing countries in the global trends towards information societies. We begin with, in Section 3.1, a quick look of the state of affairs in international technology transfer that makes up external conditions for the acquisition of technology by developing countries. We then analyze (Section 3.2) technological choices in correspondence to the external conditions on the one hand, and factor endowment of developing countries by adding—if they are capable to have it, factors of technological and institutional capabilities to the conventional ones, on the other. This is followed by a review (Section 3.3) of experiences in Taiwan (Province of China, thereafter simply Taiwan) in comparison with Korea (Republic of, thereafter simply Korea or South Korea), to explore on learning effect in network-based firms structure. The review indicates to the distinctive emphases for technology policy: a, freeing for small entries; b, improving technological infrastructure and supportive institutions; c, human resource development; and d, proactive and adaptive policy-making. In the final Section 3.4, we sketch current move in innovation policies in a few Asian economies.

Section 4 ends up the paper by calling for theoretical recourse. We compare highlighted policy areas with conventional thoughts; the later took (physical) capital investment as the sole or major factor, gave overwhelming weight on large firms as the pivotal organizations, and dealt with policy-making in the way either direct intervention or '*laissez-faire*'. Although practical adjustments in policies have appeared to take in many developing countries, there is a need for 'paradigm shift' of development policies, if developing countries are to cope with changing domestic and international conditions with greater consciousness.

2, IT Revolution and the Information Societies

2.1, Information societies and learning economies

The drastic progress in information technology has made it possible to reduce costs and increase efficiency in coding, recording, processing, transmitting, and receiving information of all kinds. With this progress, academics, one of the most and earliest benefited sectors, are worldwide connected and in instantaneous exchange. Information about finance, business and public affairs, and education and training, are increasingly accessible at the WWW sites, fostering the development of so-called e-banking, e-business, e-government, e-learning, and so on. Since the mid-1990s the pace of information accessibility is accelerating by the plans such as those to construct information superhighways (United Sates), information societies (Europe Union) and many others; they endured the development of a 'global information infrastructure'.

Information societies imply the societies where information is abundantly produced and circulated. The explosively flourished availability of information offers an important component to the knowledge infrastructure that supports for the societies in learning and capability building. On the other hand, such augmented knowledge infrastructure cannot, by itself, replace for human's learning efforts. Just on the contrary, learning and capability building in order to select, absorb and make use of relevant information for solving problems so as to create social and economic value, become ever more critical. 'Learning economies' hence is used to describe the most critical learning factor attributed to the dynamics of information societies, as Lundvall places it: 'there is no alternative way to become permanently better off besides the one of putting learning and knowledge-creation at the center of the strategy (by Lundvall, quoted from Mansell and Wehn: 51).

It is in this connection that we need to emphasize broadly defined terms of 'learning' and 'knowledge', for the analysis of this paper. *Knowledge* includes practical skills established through learning by doing as well as capabilities acquired through formal education and training, inasmuch as the knowing capacity of persons is concerned. *Learning* is the process in which the learner sorts out and uses information upon his knowing capacity to solve problems and, as a result, produces new knowledge. Learning occurs in all economic and social activities including R&D, production, marketing, management, and policy and political practices; hence learning is *collective or social process*, carried out in human relations. In the information societies learning possibilities spread. It allows wider participation of people. However, the full benefits of information technology can be realized only through a process of social experimentation. It is a process associated with major changes in the relationships between producer and user of goods and services, and in patterns in which division of labor are organized and coordinated.

Table 2 depicts the main characteristics of IT-based socio-economic organizations, namely, the so-called 'information societies', in comparison with the old 'Fordist' mass production economies. The comparative outline as such was suggested by students in the field of innovation studies some years ago, it now has been proved and widely accepted alongside the evidence revealed in advanced countries.

Table 2: Changes in Techno-economic Paradigm

'Fordist' (Mass production economies)	*ICT-based (Information societies)*
1, Energy-intensive	1, Information-intensive
2, Standardization	2, Customized
3, Rather stable product mix	3, Rapid change in product mix
4, Dedicated plant and equipment	4, Flexible production systems
5, Automation	5, Systemation
6, Single firm	6, Networks
7, Hierarchical management structures	7, Flat horizontal management structures
8, Departmental	8, Integrated
9, Product with service	9, Service with product
10, Centralization	10, Distributed intelligence
11, Specialized skills	11, Multi-skilling
12, Minimal training requirements	12, Continuous training and re-training
13, Adversarial industrial relations; Collective agreements codify provisional armistices	13, Move towards long-term consultative and participative industrial relations
14, Government control and planning and sometimes ownership	14, Government information, regulation, coordination, and 'Vision'
15, 'Full employment'	15, 'Active Society'
16, Emphasis on full-time employment for adult (16-65) male workers	16, More flexible hours and improvement of part-time workers and post-retirement people

Source: Slightly modified from Mansell and Wehn (1998): 49; originally from Perez, C. and Boyer R. in Freeman, et al. (1991)

To better understand the numerous items included in the Table, we reorganize them into four dimensions.

1, The mode of technological innovation (items 1 to 5): Technological change takes faster paces in information societies. This is evolved along with broad accumulation and distribution of experiences and competences, and supported by enormously improved connectivity and communications among knowledge producers and users. Technological systems become complex; architecture and source code of complex systems tend to be open. The development of networks structure for innovation participants, and flexible specialization among them, strengthens the capacity in handling innovation of complex technological systems. With the opening of complex systems, competition moves to the development of particular applications in which multi-disciplinary knowledge is increasingly involved.

2, The organization of division of labor (items 6, 7, 8, 9, and 13): In information societies network relationship between firms becomes of strategic importance (this does not mean that large firms will be wiped out entirely). Inside firms, hierarchical structures tend to become flattened and information flows travel more among functional units.

3, The structure of skills and labor markets (items 10, 11, 12, and 16): Labor in information societies reach to higher levels of general inelegance; they thereupon develop specialized-skills rapidly. Jobs become flexible.

4, The role of government and the relationship of government with people (items 14 and 15): With the information being transparent and accessible, participative policy-making enhances policy and political learning, and therefore the so-called 'social capability' in making change and dealing with shocks. The role of government moves from control to coordinating the development of governance orders.

It is worth noting that the social and political transformations in OECD countries are still in their ways and to interpret it much is left for further studies. The transformations are difficult and uncertain; restructuring education system and labor market are just two of the many difficult issues. Furthermore, paths of the transformations are specific to particular countries. Hence United States and Japan make their measures for solving employment issues distinctively. Nevertheless, the featured orientation of the transformations as outlined is convincing. It is in the sense of general orientation that we shall adopt them in the discussion in the following sections.

2.2, Opening systems, networks and flexible specialization

Of the four dimensions, the latter three concern social and political aspects of the transformations to information societies, and the first relates to technological imperatives that lie behind the transformations. It is useful to elaborate the technological imperatives, reflected in the emerging mode of technological innovation.

As we have said, in information societies technological change goes faster. Explosively flourished availability of information expands the knowledge infrastructure that in turn accelerates learning and capability building. Why could they do this? What opportunities and challenges arise from this for developing countries? Answers will be explored around the terms of 'open systems', 'network structure', and 'flexible specialization' that characterize technological innovation and knowledge structure in the emerging information societies.

--*Modular structure of technological knowledge and open systems*

The possibility of opening systems rests on the development of 'unit' or 'modular' structure of complex technological systems. 'Unit' structure, seen in continual manufacturing such as oil refinery, petrochemicals, steel and semantics (Rosenberg and Nelson 1994), and 'modular' structure, in discrete manufacturing such as machinery and electronics (Ulrich 1995) is developed, as technologies grow increasingly complicated and sophisticated. Unit and modular structure allows a 're-usability' of engineering labor and capital investment so that further product diversification or process improvement take shorter lead time and at lower costs. Although such trends in organizing complex systems have long existed in engineering design, they are now supported powerfully by the new means of information technology. The knowledge structure of complex systems serves a technical basis for open systems and network-based flexible specialization.

The IT industry is itself typical of modular structure and open systems. Software writing has been taking the modular way to save technical work and improve quality. Opening source code of software, available for other developers free of charge, was the way of software development before the 1970s. Although Microsoft started making software proprietary and turned it into a big business in the late 1970s, sharing source code among software developers never stopped, it is practically normal in Internet server development. It seems that open source software like Linux is now gaining stronger momentum, since '(the) industry is learning that there is value in deep co-operation as well as in hard competition.' (The Economists Apr 12th 2001), which is only possible if based on shared source software.

--*Why does opening systems facilitate network-based flexible specialization? The case of Silicon Valley*

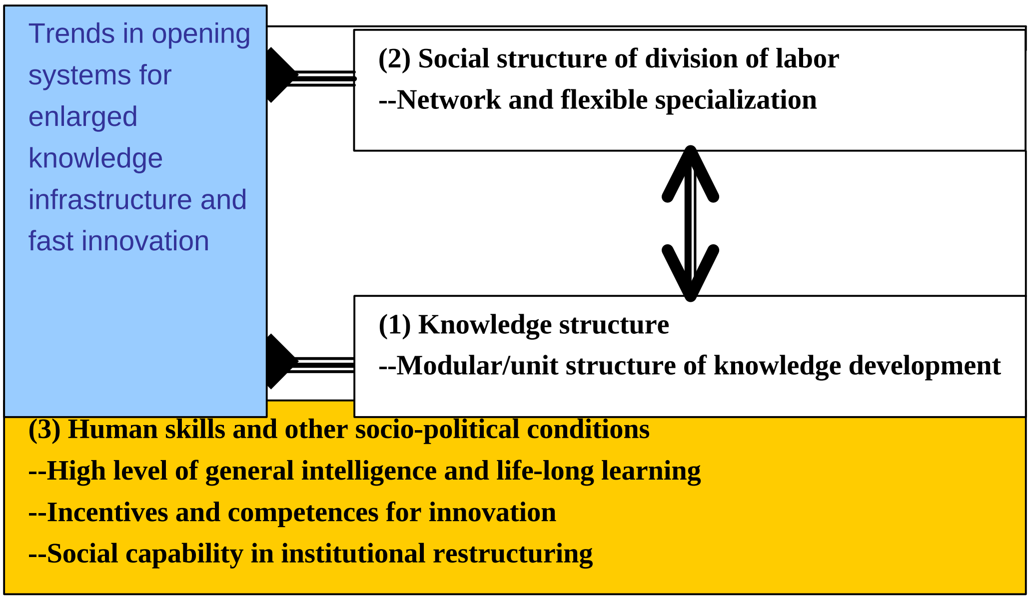
Opening code and architecture of computer systems is considered (Saxenian 1994) the key property with which Silicon Valley succeeds. In Silicon Valley, Sun Microsystems pioneered the trends in the mid-1980s, in response to the competition pressure from Japanese firms. Since Sun recognized that it lacked the resources to develop the broad range of skills and competencies for bringing their innovation into the marketplace. With the opening, Sun's business, and Silicon Valley by and large, turned to be flourishing in the following years. Backed up by shared knowledge in terms of architecture and interface codes, new entrants were coming in, experimentation took place widely at much more nexus, and improvements in subsystems, parts and components were communicable and compatible to be integrated into new systems.

Firms' ecology, namely, relationship between firms, changed as well with the sharing of knowledge about systems. In Silicon Valley, disintegrated and highly specialized firms were growing, some were specialists in designing parts, components and systems; some others were specialists in processing functions, they invented the use of low-cost, low-volume, and flexible 'mini-fabs', such as for assembling printed circuit board and silicon foundry. It is reported (Saxenian 1994:120, 150-156) that by the early 1990s, two thirds of the Silicon Valley semiconductor companies were 'fabless', co-existed with flexible mini-fabs. As the IT market changes fast, the specialist firms adjusted themselves swiftly. This was because costs for adjustment had dispersed to many companies, and the companies were professional on specialized areas hence capable of handling risks. Alongside, shared knowledge basis permitted the creation of new systems by integrating innovations made from sub-systems and parts.

--*Interaction between technology and society*

Obviously the trends in network structure and flexible specialization vary between technologies. It is prevailing, to various extents, in the technological areas that the production of the technology takes discrete process; namely, sequential steps of the production are not necessarily connected, in contrast to so-called continual process (see Section 3.2 and Table 4). Of which the IT industry is one with the strongest possibilities towards network structure. The opening of systems architecture in effect turns proprietary knowledge into shared knowledge infrastructure for a network community, thereupon division of labor is deepened and innovation activities intensified. By this way, the capacity of network community is expanded to creating higher added values. As Don Kash puts it: 'organizational networks…carry out repeated innovation of complex technologies.'[1]

Figure 3: Emerging Mode of Technological Innovation and Information Societies



Network structure and flexible specialization are ways or patterns of organizing division of labor, resulted from interaction between technology and social settings. Similarly, human skills, labor market and other socio-economic conditions have to be in match to technology, as well as in match to each other. Inter-relationship among these dimensions is depicted in Figure 3, where functional block (1) represents the mode of knowledge structure of technology systems, and functional block (2) and (3) the modes of social structure for division of labor, human skills and other socio-political conditions, respectively.

To all of the changes in functional areas (1), (2) and (3), the revolutionary IT plays a role as a catalyst, by lowering the costs for management, transactions, and knowledge codification and dissemination. And all of the changes in areas (1) (2) and (3) reshape so-called knowledge infrastructure supportive to further change in technology and society. Such knowledge infrastructure is not only supportive in the place where it is yielded; it is also worldwide penetrating especially when the world is becoming closely interconnected.

[1] Don Kash: Culture and Technological Innovation, lecture provided in the Zhong-Guan-Cun Innovation Forum, Beijing China, 24 April 2001. Many researchers have reported on the emerging mode of technological innovation and related change in division of labour. Gibbons et al. (1994) term 'mode 2' for the new ways of knowledge production in which innovation participants are widely socially distributed, in contrast to the old mode in which only professional R&D institutions are the loci of knowledge production. Badaracco (1991) describes firms in the network structure as of open manor houses; knowledge links are intensive among them.

3, Strategic Choices and Capability Building for Developing Countries: Conventional versus New Approaches

3.1, International technology flows and intellectual property rights

The picture the above developed provides a reference framework, as what groundbreaking features likely to be in the socio-economic transformations in conjunction with the IT revolution. More specifically, the emerging mode of technological innovation and knowledge production conveys the makeup of a widespread ‘technological (or knowledge) infrastructure’, which is also open and available for developing countries, if they are capable of making use of it.

Ostry and Nelson (1995) term the movement in the intensification of international knowledge flows as ‘knowledge globalization’. This is happening in parallel to technological progress and worldwide trade expansion. The travel around of knowledgeable people, the codification of knowledge either embodied in physical artifacts or documented in patents, technical manuals, textbooks and professional literature which are migratory accompanying with traded and non-traded terms, compose the international knowledge flows. Not only technological knowledge, but also massages about market and consumers tastes being widely circulated, is attributed to speeding up dissemination of innovation, so argued by Ostry and Nelson. This should be a move in favor of developing countries. They, having limited technological sources accumulated internally, unavoidably rely on external sources to stimulate entry and learning.

Dreadfully meanwhile, the 1980s and 1990s saw a fierce tightening of intellectual property rights. The protection of IPR has been tied up, as the WTO rules did, with trade conditions, known as Trade-Related Intellectual Property Rights (TRIPs). In these rules any presumed violation of IPR might be punished in trade terms. This surely increases the costs developing countries to pay for proprietary technologies. More seriously, it would close the appropriateness, as argued (e.g. Bello 2001), of many policy measures such as ‘reverse engineering’, which were taken for successful catching-up of the NIES in the 1960s and 1970s (see Linsu Kim 1997 for South Korea).

Corresponding to the two sides of the sate of affairs in international technology trade, there have been pessimistic and optimistic views co-existing with regard to the fate of developing countries. They are disparate to each other so visible that some predict about the end of catching-up ‘miracle’, that what was achieved by the Asian NIEs would no longer be possible for their followers because of the heightened trade protectionism and tightened IPR; some others believe in leapfrogging that quickening development process or even jumping over some stages that advanced countries had gone by is now feasible than ever; such opportunities for developing countries are opened by IT revolution.

To reflect to the arguments, the author, although not pessimistic with regard to the future of developing countries, wonders the soundness or usefulness of the leapfrogging view. The leapfrogging argument makes little sense if it implies that developing countries would not necessarily pass through all the generations of some certain technology such as that for telecommunications that advanced countries had used. Furthermore from the point of view of learning and capability building, which emphasizes the essentially cumulative nature of gaining mastery for technological and social change, the leapfrogging statement might be misleading to instigate unrealistic ambition at the expense of careful accumulation of knowledge and competence. The author suspects also the argument that the IPR would unbendingly close up development opportunities. This argument does not distinguish among various technologies, on whose diffusion the restrictive effects of IPR differ. The argument does not consider learning efforts as well, with which developing countries might change their negotiation position in international technology trade. It should be admitted however that there are problems with international trade order, as it stands now, but this is not the focus of the paper.

Following Section 3.2 examines the old issue of technological choice, by taking into account the emerging character of innovation and knowledge infrastructure. Factor endowment of developing countries makes up their ‘comparative advantages’, to which we add the learning related, i.e., the technological and institutional capability factors to the traditional capital and labor factors. Section 3.3 illustrates learning dynamics in network-based firms structure in Taiwan in comparison with Korea, and outlines some major elements for the dynamics. Section 3.4 collects recent evidence in Korea, Hong Kong (SAR of China) and China in innovation policy, to correspond to the discussion in the previous sections.

3.2, Technological choice and factor endowment of developing countries

Technological choice paves gateway for developing countries to enter into modern sectors. It is an important part of technology policy for development. We would like to see what choosing opportunities are likely opened and what endogenous efforts might improve the position of developing countries in selecting their entrances.

Technology is to be scrutinized. We consider a technology as if a), it is simple or complex technology; b), production of the technology is based on discrete process or continual process; and in discrete production, to distinguish between small batch, large batch and mass production. The impact of opening systems is stronger for discrete-produced technologies. More access opportunities occur to the discrete than the continual if producer’s conditions being identical. Associated with the discrete technology is also flexibility in firm’s organization, meant that both single firms and networked firms are possible for their production; actual mode of the organization depends on other reasons such as path-dependency; and c), it is mature or fluid (namely, fast change) in its life cycle (see Utterback 1996). Often we assume that a latecomer producer can only start with mature technology, regardless it is simple or complex, or discrete or continual.

As for producer’s factor endowment, to the traditional capital and labor we add engineering capability (or engineering intensity) to indicate the absorptive and adaptive capacity of the developing producer. Human capital development, input in R&D and experience with design and testing engineering, combined, approximate the engineering capability factor. Besides, we consider institutional capability to indicate the management and coordination capacity of the producer in managing single firms and handling linkages between firms.

Accordingly we get an illustrative map as shown in Table 4. In the left column are the technology/product groups. They include: 1) traditional manufactured and simple mature modern products; 2) Mature complex systems produced in mass production or large batches; 3) mature complex systems produced in small batches; 4) mature bulk intermediate goods which is produced in continual process; 5) machinery producer's goods and services; and 6) IT producer's goods and services. Each technology group gives example products in the parentheses; hence for Group 1 the exemplified products are clothing, toys, shoes, and simple electronic components. Characteristic processes of the technologies are put in the second column, in which Groups 5 and 6 are particularly assigned with 'user-customized', to indicate the increasingly strong tendency in specialization and diversification, because technologies for producer's goods and services have in particular to be developed to cope with the need for customized final goods and services.

Corresponding producer's factor endowments are appeared in the right column, to point out what factor combination in terms of capital-, labor-, and engineering- intensity is involved in producing the certain technology/product. Thus we have high labour-intensity, low capital-intensity and low engineering-intensity that are involved in the choice of Group 1 technology. One sees also 'small-medium firms' appeared there, implying that the production of Group 1 technology is often (but not definitely) carried out in small firms. Here institutional factor is expressed in simple terms of firm's size. We specify characteristic firm's size only for Groups 1 and 4; for Group 4 'large firms' are necessary in order to achieve scale economies. We do not specify firm's size for Groups 2, 3, 5, and 6. These technologies can be produced either in larger firms or networked smaller firms as has explained.

Traditionally, developing countries with scarce capital and abundant labor were advised to go for low capital-intensity and high labor-intensity technologies, remarkably textile and other light manufacturing, which fall in Group 1. The successful Asian NIEs, however, paved their distinct ways. Korea and Taiwan for example, started with Group 1 though, moved up to all the Groups 2, 3, 4, 5 and 6 and developed respective competitive strengths in these technologies. This was because they improved technological capability and managerial skills fast through enhanced learning, that transformed their factor endowment to become competitive advantageous for technologies at higher ranks. The ways they took are beyond the highlights of traditional thoughts.

It is remarkable that for entering Groups 2, 3, 5 and 6,[2] required capital investment is not very high and absorbed labor is not very few which should be said not disfavoring developing countries. However, if failed in improving engineering and managerial capabilities, the chance of entering these groups would be closed. This is a situation repeatedly happened; it hauls a developing economy stuck at primitive industrialization and fallen in poverty, where even massive exporting cannot help. Some authors describe it as 'low-equilibrium trap'.

[2] This framework cannot explain for the choice of Group 4 technologies, which use capital highly intensively and employ little labour. Both Korea and Taiwan entered in Group 4, presumably for inter-links of the economies. Apart from this, Korea produces group 4 technologies (steel and DRAMs) with a primary aim at international market.

Table 4: Technological Choice and Comparative Advantage for Entry

Technology/product group	*Process characteristics*	*Producer's factor*
Group 1: *Traditional manufactured and simple mature modern products* (Clothing, toys, shoes, simple electronic components)	Discrete processing; Small or large batch production	Small-medium firms; High labour-intensity; Low capital-intensity; Low engineering intensity
Group 2*: Mature complex systems* (Consumer durables, personal computers, automobile)	Discrete processing; Mass or large-batch production	Modest labour intensity; Modest capital intensity; Modest to high engineering intensity
Group 3*: Mature complex systems* (Electric power plants, shipbuilding, railroad-related equipment)	Discrete processing; Small batch production	Modest to high labour intensity; Modest capital intensity; Modest to high engineering intensity
Group 4*: Mature bulk intermediate goods* (Steel, cement, glass, basic chemicals, and DRAMs)	Continual processing; Mass production	Large firms; Low labour intensity; High capital intensity; Modest engineering intensity
Group 5*: Machinery producer's goods* (Machine tools, flexible manufacturing centres or lines)	Discrete processing; Small batch and user-customized	Modest to high (skilled) labour intensity; Modest capital intensity; High engineering intensity
Group 6*: IT producer's goods* (Various data processing systems, software, CPUs, and ASICs)	Discrete processing; Small to large batch and user-customized	Modest to high (skilled) labour intensity; Modest capital intensity; High engineering intensity

Source: The first column 'technology/product group' is from Vernon (1990) with modification. Vernon, attempting to link up between technology and trade, developed this classification of technology by adapting Keith Pavitt (1984). The producer's factor in the right column is the author's.

The oversimplified analytical scheme has led to the message that the mastery of engineering capability and institutional skills enables a developing economy to keep away from low equilibrium. This is coherent to the successful experiences in Korea and Taiwan, and earlier, the experience of Japan. Keeping this in mind, we now turn to explore what we can learn from the case of Taiwan about network-based learning dynamics.

3.3, Learning dynamics in networks

The Asian NIEs approaches to learning and capability building have in many instances been generalized as identical, where 'reverse engineering' and 'claiming up a capability ladder' from OEM (original equipment manufacturing) to ODM (own design manufacturing) to OBM (own brand manufacturing) (Hobday 1995) are widely cited. A close review demonstrates that they differ from each other significantly as well, particularly in firms structure, in spite of the fact that all learned fast and all invested a great deal in human capital and R&D.

Among the so-called 'first tie' NIEs, South Korea is representative of large firms dominated-structure, and Taiwan in contrast, small and medium firms structure, developed from their historical and political contexts respectively. Singapore and Hong Kong are closer to Taiwan as far as firms structure is concerned. For our purpose, it is instructive to look closer into learning dynamics in the case of Taiwan, in linking it with the emerging innovation mode and knowledge structure that is characteristic of opening systems, network relationship between firms and flexible specialization.

Let us have a general picture first. It is reported[3] that in 'engineering' sectors (namely machinery and electronics sectors), firms' concentration degree in Taiwan is considerably low. In the industrial machinery sector, 96 largest Taiwanese business groups produced 9.8% of the total sales, in comparison, 50 largest Korean *Cheabols* made up 34.9% of the total. We have more similar pairs of percentage: in the electronics sector it was 22.7 % versus 50.9%, for precision instruments, nil versus 14%, and for transportation equipment, 39% versus 79%. The calculations are made based on the mid-1990s data. Obviously small firms dominantly compose the Taiwanese economy.

Both Korea and Taiwan are excellent in development performance. In spite of this, the two economies developed differentiated competitive strengths. In line with our technology grouping, Korea, by the 1990s, developed competitiveness in Groups 2, 3, and 4 (mature complex systems processed in mass or large batch production; mature complex systems produced in small batches; and mature bulk intermediate goods). In comparison, Taiwan showed competitiveness in Group 5 and especially Group 6 (IT producer's goods and services and machinery producer's goods and services). In the IT industry, Taiwan was impressively strong in such as motherboards and mice (above or around 80 percent of the world market), image scanners, monitors, and keyboards (all being above or around 50 percent of the world market), and ASIC (application specific integrated circuits), according to the average 1990's record. Korea, in comparison, had the strengths in consumer electronics and massively produced components like DRAM, which are located in Groups 2 and 4 respectively.

How did they learn then in the networks in Taiwan? How did the small size-dominated firms structure supported learning in Taiwan at least as good as in Korea? What was the relationship between firms structure and competitive strengths? We touch upon theses questions by reviewing two industries: the sewing machine industry in which Taiwan has become the largest supplier since the 1970s (Shive 1978; Hobdy 1995) and the IT industry (Hobday 1995, Chiang 1990; Hou and Gee 1993).[4]

--*'High' entry and forward and backward linkages*

To analyze network-based learning, network-based factors are crucial, while learning in isolated single firms is a matter basically delineated by firms' strategy and conducted within the territory of firm. Schmitz and Kadvi distinguish between 'passive externalities' and 'actively purposed externalities' (1999) for network-based learning.[5] In Taiwan it is the actively purposed externalities that have supported the excellent performance, of which *'high' entry and forward and backward linkages* (in contrast to 'reverse engineering' which is suitable for single firms) are pertinent to describe the work of networks for learning. Passive externalities, if being restricted in it, may only maintain inferior and

---

[3] Working Paper 5887, National Bureau of Economic Research, Washington D.C., cited from Juana Kuramoto, INTECH Mimeo, 1998.

[4] For a more detailed analysis, see Gu 2000.

[5] 'Passive externalities' mean the economic and learning effects that incidentally exist with the firms cluster in a geographically adjacent area. Whereas the notion 'actively pursued externalities' refers to the economic and learning effects, which are developed through purposeful joint action.

less dynamic networks, seen in many developing countries.

'High' entry in Taiwan included the entries of foreign technology, which were related to Foreign Direct Investment (FDI) and technological licensing. High entry was also maintained in association with the entries of domestic small high-tech companies, which were mostly spun off from state-owed R&D institutes. The latter, the domestic high entries, was more significant for the IT industry. 'High' entry destroyed 'low equilibrium', intrigued more entries to take the niches created; and purposeful promotion for forward and backward linkages spread skills and knowledge all over the many loci of network structure. Accordingly wave-by-wave the networks grew larger in terms of links and deeper as knowledge basis.[6]

--Local supportive institutions and technological infrastructure

Supportive institutions helped enormously in training, standardization and other technical and managerial assistance in Taiwan. Unlike the case of single firms-based learning where individual firms with their deep pocket internalize many supportive functions for learning and capability building, network-based structure has to have strong and widely accessible technological infrastructure for many small users.[7]

Supportive functions are also contained in networks stricture itself when they grow. In Taiwan, specific networks such as that for trading (Egan and Mody 1992; Levy 1991), parts and components which is usually described as sub-contracting networks (Ernst 1998; Levy and Kuo 1991; Schive 1978),

---

[6] In the sewing machine industry, the first wave of learning came with the investment of Singer. Skills and knowledge brought about by the entry of Singer included that for parts and product specification, for production engineering, and for management techniques like accounting. The skills and knowledge were widely disseminated by the government's coordination, so that in a few years 160 out of 250 local producers were renovated to become capable parts suppliers to Singer. Some local sewing machine producers grew fast as well, relying upon the supply of quality parts and components which had became a strength of the sewing machine network in Taiwan. The next wave came following the investment by a few Japanese companies. To the Japanese investment the capacity of the Taiwanese industry in quality parts supply, marketing and information channels were important motives. With the coming of the investment, the cluster of the Taiwanese sewing machine industry was once again renewed and reinforced by means of the forward and backward circulation of knowledge and skills.

In the IT industry, Philips and Sanyo were important foreign entrants (Hobday 1995: 109-111; Chiang 1990). Philips played an important role in stimulating local entry and local supplier network, partly because the strategy of Philips was rather niche market-oriented, reflected in the items of ASIC and liquid crystal monitors which were consist with the firms structure and business environment of Taiwan. Local high entries were largely spin-offs from government-run R&D institutes notably ITRI (the Industrial Technology Research Institute); they entered higher-end or upstream of the IT industry, such as semiconductors for specific applications, and software. One of the best known spin-offs was TSMC which focused on specialist chips, TSMC was also one of the first companies in the world able to offer specialist chip foundry services for Taiwanese and Silicon Valley chip design companies. Local semiconductor design houses had developed to 40 in the late 1980s, most of them were designing special applications chips, and many were ITRI's spin-offs. Local small niche-entrants focused on relatively downstream areas, produced outputs such as parts and subsystems; they were supported to upgrade in knowledge and skill mastery. Large entry did occur as well in the Taiwanese IT industry. Tatong, a state-owned firm, exemplifies the entry; it had developed some strengths in consumer electronics.

[7] The government of Taiwan financed for R&D heavily, roughly responsible for almost half of R&D expenditure in many years. Remarkable is the role of ITRI (the Industrial Technology Research Institute) in Taiwan which has been a springhouse for local high entry for the IT industry, as has mentioned. In Korea it is instead large firms who financed and performed increasingly large part of such activities. In 1995 the Korean government took for only 19% of the total R&D expenditure (OECD 1999: 31).

classmate and professional 'peer' networks (Ernst 1998), and networks between academics, technological infrastructure and their industrial users which the government policy promoted focally (Hobday 1995; Ernst 1998; Chiang 1990), were components of the overall framework structure. The network structure as such is distinctively open. Particularly, it is internationally connected, provides precise nodes for international flows of technology and knowledge.

--Human resource development and a proactive 'catching-up' culture

Commonly for both Korea and Taiwan, human resource development provided internal bases for intensive learning to master skills and competences. To gauge their human resource development, we use the data on educational level of labor force demonstrated in Table 5 below. The paces of Korea and Taiwan in educational improvement have been significantly superior to China and India in the period examined. The distinction in educational performance is in parallel to the distinction in economic performance between the two pairs.[8]

Table 5: Adjusted Years of Education Per Person Aged 15-64, 1950-92

Year	*Korea*	*Taiwan*	*China*	*India*	*Japan*	*UK*	*USA*
1950	3.36	3.62	1.60	1.35	9.11	10.84	11.27
1973	6.82	7.35	4.09	2.60	12.09	11.66	14.58
1992	13.66	13.83	8.50	5.55	14.86	14.09	18.04

Source: Maddison 1998: 63. Primary education is given a weight of 1, secondary 1.4, and higher 2.

In common as well is a 'catching-up' culture, which motivated for proactive policy-making and collective learning in the cases of Korea and Taiwan. Political stability was a prerequisite for this, and initial success in some areas might have provided demonstration effects for a 'can-do' attitude to grow.

To sum up, the case of Taiwan offers good evidence to show that an internationally accessible knowledge infrastructure did have developed, as for the IT industry and the machinery industry examined. The openness of complex systems made it feasible that the small firms-dominated IT and machinery industry in Taiwan maintained improving competitiveness continuously, although they themselves did not invent the technology, nor did they run the frontier of the technology when they were gaining some competitiveness. Small firms-networked structure seems to be apt at the technologies which are in rapid change and which have various diversified applications. It might be also that—it needs more evidence, by penetrating into the world production systems the restrictions that a tightened IPR regime imposes would be less impeding. Moreover, small firms-dominated structure seems to be more flexile in cope with external shocks. The economy in Taiwan was less influenced by the 1997 financial crisis while many Asian countries were hit hard. Table 6 recaptures learning and capability building in network-based innovation system and in single firms-based innovation system, in terms of learning process, supportive function/institution and needed human resource. .

8 Human capital serves a potential foundation for facilitating absorption of knowledge and technology streamed from international sources. It makes up the nearly only initial internal learning assets of developing countries. But this does not imply that highly educated labour force alone determines learning performance, many other factors at work, some have been discussed and some others did not, such as demand side factors.

Table 6: Learning and Capability Building, Network-based and Single Firms-based

	Network-based learning	*Single Firms-based Learning*
Learning process	Induced more by demand***;*** 'High-entry and forward and backward linkages' over the network; Open to various flows of knowledge and friendly to new and small entries	Directed by firm strategy; Reverse-engineering within the territory of firm; Relatively isolated from new and small entries.
Supportive Function/institution	Served largely by external supportive institutions; Widely accessible innovation infrastructure is critical.	Largely internalized in firms; Political alliance with the government is critical.
Needed human resource	High; Decision-making on technology and business is decentralized and spread	High; Decision-making on technology and business is dominantly in the hands of technical and business elite.

Network-backed learning approaches are not necessarily identical in different circumstances. Singapore for example absorbed FDI-related technology in distinctive ways. Instead of local content requirement for FDI that Taiwan took to facilitate forward and backward linkages, Singapore approached learning by means of local content 'competing-for' and 'squeezing-in' foreign invested products and services, so as to gain the share of highly added value. Local small parts and process specialists grew more around multinational companies (MNCs); meanwhile to back them the government set up programmes for education and entrepreneurship, these programmes thoughtfully included the partnership of MNCs (Wong 1999).

With the IT revolution and information societies proceeding to unfold full range of significance, we have reasons to believe that the network-featured learning approaches represent the orientation for the future. We have outlined major policy areas for such approaches, in which freeing for small entries, building-up technological infrastructure and supportive institutions and human resource development are very central. And to cope with fast changes, policy-making itself needs indispensably to be proactive and adaptive.

3.4, Current move in innovation policies in some Asian economies

Current move in innovation policies confirms the discussion we have made in the above paragraphs. We take three cases Hong Kong, Korea, and China to illustrate what are likely to happen there. Spreading education opportunities, granting strategic importance to small initiatives, and improving information and technological infrastructure are in common in these cases, although particular focuses are made in response to particular problems in respective contexts.

--*Hog Kong (Special Administration Region (SAR) of China)*

Hong Kong adopted a *laissez faire* development policy until recently. Hong Kong focused on providing a stable administrative and a free market regime, but did not forcefully promote technology and innovation. As a result, Hong Kong has been competitive in light manufacturing and services such as for transportation and banking, but lacked technological depth. Squeezed by high labor and land costs Hong Kong was relocating its manufacturers largely to South China in the 1980s and 1990s, and since the 1990s, Hong Kong suffers additionally from eroding re-exports and declining tourism; the hit of the 1997 financial crisis exacerbated the problems further. In response, the new SAR leadership of Hong Kong determined to embark on reforms to transform Hong Kong to an innovation and knowledge-based economy. Following the Eight Points represent the vision and action taken by Hong Kong now for the strategic transformation.[9]

(1) *Proclaim Government Commitment,* to give Hong Kong a new outlook and set the stage for concerted action. In 1998, the Hong Kong SAR Administration declared its IT strategy—'Digital 21';
(2) *Strengthen Education,* to provide educational opportunities to people in all strata of the society in order to bridge the knowledge divide;
(3) *Invest in R & D,* and by leveraging on the capability and human resources of China and with international collaborations, to enable Hong Kong in making significant achievements on selected areas in a relatively short time;
(4) *Promote Industrial Technology Development,* to bridge the gap between research and commercialization. Preparation work for the Applied Science and Technology Research Institute has commenced;
(5) *Build Science Parks,* to incubate technology businesses and new ventures, and to network science parks in the Hong Kong-Pearl River Delta (of China) area. Phase One of the Science Park plan is in progress;
(6) *Provide Incentives for Businesses to improve technology;*
(7) *Establish Venture Capital Funds for SME,* to facilitate the launching of innovative initiatives and to encourage innovation and entreprenaurism; and
(8) *Broaden the Technical Capability of Government,* to upgrade their knowledge of current technology and the ability to take actions in response to changing needs.

--South Korea

South Korea adopted strong interventionist policy proactive to technology and industry. An alliance between large industrial conglomerations (*Chaebols*) and the government lent the ground for the single firms-based learning approach. By the 1990s, from a labour-intensive exporter Korea had became competitive in capital- and technology-intensive products, such as automobiles, semiconductor memory chips and consumer electronics. Weak part of the Korean innovation system is in 'thin' linkages between firms and between sectors, small initiatives were subdued in a long time.

New progress came out in the late 1990s. In response to the financial crisis the Korean government

---

[9] See http://www.ust.hk/%7Ewebvprdo/Program8S&T.htm for policy remarks by Otto C.C. Lin, Vice President, University of Science and Technology of Hong Kong; and formerly the founder and first President of ITRI, Taiwan; and http://www.info.gov.hk/digital21/e_index.html for policy statements by Mr. Tung Chee-Hwa, Head of Hong Kong SAR.

fostered disciplines for banking system, urged *Chaebols* to transform their large and multi-branched structure into core business-based smaller companies. Good and factor markets were deregulated to be conducive to risk-taking ventures. Particularly, the 1997 Special Act for the Promotion of Venture Business lends the policies supportive for small initiatives. A group of SMEs, called NTBF (new technology based-firms), therewith emerges, which is engaged in new technologies mostly IT and biotech. By June 2000 the total of NTBF reportedly reached to 7,000. The birth of SMEs and the transformation of *Chaebols* go hand by hand: in parallel to the restructuring of *Chaebols,* well-trained scientists and engineers who had been laid off by *Chaebols*, turned to the NTBF. Whereas Korea had since the 1980s attempted to correct its institutional weakness anxiously, it seems only from the late 1990s that policy measures to a remedy gain real stimuli. As *chaebols* reduced their R&D activities during the crisis years, the technology-based SMEs increased the investment, so that overall corporate innovation activities did not shrink (Kim 2000). Korean scholars (Youn, Kwon, and Kwon 2000; Choi 2000) see it a signal indicating to a ‘paradigm shift’. They expect that the Korean innovation system would thereby turn from *Chaebol*-oriented industrial structure to become the one having more balanced large-small firms structure; and this would support for a change in the growth pattern in Korea, from quantitative expansion-led growth to innovation and knowledge-based development.

--*China*

China took a centrally planned regime in the 1950s to 1970s when technology and heavy industry were priorities of investment. The market reform of the 1980s and 1990s reduced barriers to international trade and to new entries in economic activities. Science and technology policy in this period focused on releasing accumulated expertise to be re-combined in various ways (Gu 1999a), to fit to changes in economic spheres. China in these years enjoyed high annual growth rates at or above 8 %. Living standard of people improved greatly.

That the problems of the Chinese innovation system appeared serious was also to an extent intrigued by the financial crisis. The bias in favor of urban and industrial sectors at the expense of rural people and agriculture, and the preference for large firms while discriminating against small and private initiatives were seen as profound reasons for why the strong fiscal and financial expansive policies did not work as expected, which the Government took aiming at boosting domestic consumption and investment in order to compensate for eroding exports. In addition, environmental degradation has warned that the resource-based and energy-intensive industrialization would not be sustainable in the future.

Table 7 sums up social-economic development in different historical periods in China, in terms of economic regime and development target, integration with the world economy, sector priority of investment, pattern of growth, income distribution, urban-rural relation, and environmental effect. For the periods of 1950-1978 and 1979-1999, the items of the table offer a factual record. Needed strategic revision is expressed in the column for ‘2000 and onwards’, drawn upon well-circulated debates. Surely so sketched policy for 2000 and onwards is yet to be developed into a full shape. Nevertheless, recent move in innovation policy (Xu 2000) signalizes the orientation, such as expanding educational opportunities, accelerating the development of communication infrastructure, and supportive policy measures for private and small startups. This is an orientation towards knowledge- and innovation-based development.

Table 7: Social-economic Development in Different Historical Periods in China

	1950-1978	*1979-1999*	*2000 and onwards*
Economic regime and strategic target of development	Centrally planned; Quantitative leap-frogging to develop heavy industry	In transition to market regime; Quantitative expansion of both light and heavy industry	To move to maturity of market regime; Quality of growth; People-centered development
Integration with the world economy	At low level (5-6% of GDP); Self-sufficient achieved by planned import-substitution	At higher level (20%-30% of GDP); Export of labor-intensive manufacturing, import of technology and capital goods	To be at higher level; Deepening in international specialization
Sector priority of investment	Capital goods industry; Military industry; Centralized and high R&D	Consumer goods industry; Infrastructure development; Relatively low R&D	Balanced sector structure and structural deepening; Human capital development; High R&D and intensive learning and innovation
Pattern of growth (indicated by major contribution factors to growth)	Capital investment; Through planning	Labor and capital investment; In response to international and domestic demands	Increasingly largely from human capital and technical progress; In response to domestic and international demands; Active coordination by innovation policy
Income distribution	Absolute equalitarian distribution	Concentrated to those engaged in market activities successfully and those privileged in rent-seeking; Gap-widening	Fairly equal
Urban-rural relationship	Rigid separation between industrial urban and populated agricultural rural	Temporary migration of rural population; Relative income distribution worsening	Convergence through acceleration of agricultural and rural modernization
Environmental effect	High and wasteful consumption of energy	Severe environmental deterioration	Sustainable and environment-friendly development

Sources: Gu 2001. This is the author's summary in reference to discussions at http://forum.cei.gov.cn/Forum50, and http://forum.cei.gov.cn/UnionForum, especially by HU Angang and LIN Yifu.

4, Ending Remarks: The Need for Theoretical Recourse

The Twentieth Century saw great efforts and experimentations in facilitating development of developing countries. Various essays come and go, of which the neo-classic and the developmentalist schools took the lead on policy arena alternatively. The influential developmentalist Gerschenkron's propositions (1962: 353) stand that the more backward a country's economy, the more pronounced was the stress in its industrialization on big plants and enterprises, which could be operational often only with the intervention of government. By means of large firm organization and government intervention, scarce resources were pooled up so that required high capital intensity and organizational sophistication matched. This was roughly in accordance to the experiences of Korea, the pre-war Japan, and some European latecomers such as Sweden; this also offered a rationale underlying the central planning approaches for industrialization.

The practice and the theory were a reflection to the centralized technologies used in energy, transportation and mass production that preeminently dominated economic lives from the end of the Nineteenth Century throughout the following decades. They made up the characteristic international supply of technology, and shaped the way of competition as well. The developmentalist strategy was not unbeaten, however; the failure of centrally planned economies has helped to discard doctrines like this sort, and left the stage for a resurge of the neo-classic. The neo-classic theory, while contains useful insights, is not, as was never really, instructive to latecomer economies including United States when it was relatively backward to England. Where we go? Where we go in the time IT revolution will bring and has brought about so many changes to our lives?

We need new synthesis. It should comprehend change, the essence that associated with every step-forward in the development course. It should endow the understanding that many factors are involved in any piece of change, so as to theoretically remove narrowly minded and single factor determined policy-making that the old thoughts used to entail. The work by Hayami (1997) and Fei and Ranis (1997)[10] falls in this line. They, among others, contribute greatly to the rise of evolutionary development economics. Particularly with regard to innovation policy for development, the thread of innovation systems (Lundvall (ed.) 1992; Nelson (ed.) 1993; OECD 1999) offers useful reference.[11] The innovation systems idea is originated in OECD countries in response to the challenges posed by IT revolution and information societies.

We need new analytical instrument as well. Policy areas, highlighted in the paper, such as learning dynamics, network and firms structure, small entry, human capital development and technological infrastructure, all linked to the development for the future, are new. They are not included or not well addressed in the conventional dictionary of science, technology and innovation policy for development.

---

[10] Fei and Ranis (1997) model development process as 'historical transition'. The historical transition proceeds through institutional change to develop higher levels of division of labour, and through technological learning to master superior capacity for innovation. Hayami (1997) employs an 'induced innovation model' to integrate agricultural modernization and industrial development, and combines government, community and private initiatives for an explanatory framework to be responsible for development performance.

[11] The innovation systems view takes technological innovation economics, institutional theory and evolutionary economics as theoretical background for analysing innovation policies. A summary is in Gu (1999b), which is developed from the developing countries' perspective.

In response to new policy issues researchers and policy makers from developing countries should surely draw upon innovation systems schools and many other schools, nevertheless there are problems specifically faced by developing countries in relation to the backwardness in their institutional development and technological mastery. Technological choice is one of the problems which we have had a discussion. Agricultural development and rural modernization is another one, to which both the developmentalist and the neo-classic are blind; they threw it away for the mercy of industrial expansion. Innovation systems approach would likely have a handle on it well. To solve these particular problems creative intellectual dedication and pragmatic experimentation are indispensable.

Not only analytical tools, but also a shift in minds is needed. Recall that, up to very recently, physical capital investment has been conceived as the solely or most important factor in development policy, having either the interventionist or the proponent of '*laissez-faire*' dictated the development policies. The tradition that privileges large firms and elite groups has gotten deep roots, inherited from the practice of the long past. With this legacy small entry and broad education might likely be encountered with not only operational difficulties but also social conflicts and shocks. Furthermore, adaptive and participative policy-making might be unfamiliar or disliked by the officials who used to work like a commander. Although fragmented responses to the IT revolution and information societies have appeared in developing countries, theoretical recourse helps the people and the policy makers prepared for the profoundness of the challenges, to which we are so poorly experienced.

References:

Badaracco, J. L. Jr. (1991) *The Knowledge Link*, Harvard Business School Press, Boston and Massachusetts.

Bello, W. (2001). *Why Reform of the WTO is the Wrong Agenda*
http://aidc.org.za/archives/wto_bello_why_reform.html

Chiang, J. (1990). Management of National Technology Programs in a Newly Industrialized Country-Taiwan, *Technovation*, 10:8, 1990: 531-554

Choi, Y. (2000). *Paradigm Shift in Korea's Science and Technology Policy*, PAPER presented At the International High-Level Seminar on Technological Innovation, co-sponsored by the Ministry of Science and Technology, China, and United Nations University, September 5-7 2000, Beijing, China

Egan, M. L. and A. Mody (1992). Buyer-Seller Links in Export Development, *World development*, Vol. 20, No. 3, 1992: 321-334.

Enrst, D. (1998). 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

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

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

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M. (1994). *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, London, Sage Publications,.

Gu, S. (1999a*). China's Industrial Technology, Market Reform and Organizational Change.* London and New York, Routledge in Association with the UNU Press.

Gu, S. (1999b). Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development, *UNU/INTECH Discussion Paper #9903*, Maastricht.

Gu, S. (2000). *Learning Models and Technology Strategy in Catching-up*, paper presented in the DRUID Summer Conference on the Learning Economy--Firms, Regions and National Specific Institutions, Rebild, Denmark, June 15-17, 2000

Gu, S. (2001). Science and Technology Policy in China, forthcoming in the UNESCO *Encyclopedia of Life Support Systems (EOLSS)*, section 1.30 'Science and technology policy'.

Harri Holkeri: *The Internet: challenges, opportunities and prospects*, (http://www.itu.int/newsroom/wtd/2001/ExecutiveSummary.html, 17 May 2001)

Hayami, Y. (1997). *Development Economics, from the Poverty to the Wealth of Nations*, Oxford. Oxford University Press.

Hobday, M. (1995). *Innovation in East Asia, The Challenge to Japan*, Edward Elgar.

Hou, C.-M. and S. Gee. (1993). National Systems Supporting Technical Advance in Industry: The Case of Taiwan. In *National Innovation Systems, A Comparative Analysis*. R. R. Nelson.ed. New York, Oxford, Oxford University Press**:** 384-413.

Kim, L. (1997). *Imitation to Innovation*. Boston Massachusetts, Harvard Business School Press.

Kim, L. (2001). The Dynamics of Technological Learning in Industrialisation Forthcoming i*n International Social Science Journal*, 2001

Levy, B. (1991). Transaction Costs, the Size of Firms and Industrial Policy, *Journal of Development Economics*, 34, 1991: 151-178

Levy, B. and W. Kuo (1991). 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

Lundvall, B-A (ed.) (1992). *National Systems of Innovation.* Pinter, London, 1992

Maddison, A. (1998). *Chinese Economic Performance in the Long Run*. Paris, OECD

Mansell, R. and Wehn, U. (1998). *Knowledge Societies, Information Technology for Sustainable Development,* Oxford and New York, Oxford University Press, Published for and on behalf of United Nations.

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

OECD (1999). *Managing National Innovation Systems*, OECD, Paris.

Ostry, S. and R. R. Nelson (1995). *Techno-Nationalism and Techno-Globalisation, Conflicts and Cooperation,* The Brookings Institution, Washington, D.C.

Pavitt, K. (1984). Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. *Research Policy* 1984 (13): 342-373.

Rosenberg, N. and R. R. Nelson. (1994). American Universities and Technical Advance in Industry. *Research Policy* 1994 (23): 323-348.

Saxenian, A. (1994). *Regional Advantage, Culture and Competition in Silicon Valley and Route 128.* Cambridge, Massachusetts, and London, England, Harvard University Press.

Schive, C. (1978). *Direct Foreign Investment, Technology Transfer and Linkage Effects, A Case Study of Taiwan*. Department of Economics, Case Western Reserve University.

Schmitz, H. and K. Nadvi (1999). Clustering and Industrialization: Introduction. *World Development* **27** (No. 9): 1503-1514.

Ulrich, K. (1995). The Role of Product Architecture in the Manufacturing Firm. *Research Policy* 1995 (24): 419-440.

Utterback, J. M. (1996). *Managing the Dynamics of Innovation.* Boston, Massachusetts, Harvard Business School Press.

Vernon, R. (1990). Trade and Technology in the Developing Countries, in *Science and Technology, Lessons for Development Policy*. G. R. Evenson and G. Ranis, eds., London, Intermediate Technology Publications.

Wong, P. (1999). 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

Xu, G. (2000). *China's Policy on Technological Innovation*, speech to the Closing Session of the International High-Level Seminar on Technological Innovation, co-sponsored by the Ministry of Science and Technology, China, and United Nations University, September 5-7 2000, Beijing, China

Youn, M., Kwon, Y. and S. Chung (2000). Government Policy for the Promotion of New Growth Industries--Government Policy for the Promotion of New Growth Industries, presented at the “Joint German-OECD Conference: Benchmarking ISRs” Berlin, October 16- 17, 2000
(http://industry-science-berlin2000.de/pres/kwon.pdf)