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INDUSTRIAL POLICY FOR TECHNOLOGICAL LEARNING: A HYPOTHESIS AND KOREAN EVIDENCE

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WORKING PAPERS

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Chapter 1 Introduction

Korea industrial development has recorded one of the highest growth performances over the last 3 decades, among all countries for which data is available. Furthermore, the composition of output and employment has shifted from labour intensive goods at a phenomenal pace. For example, during the early 1960s, major export items included toys, tennis shoes, human hair wigs, clothing, leather goods, tungsten ore and dried fish, etc. By the early 1990s, the major items were automobiles, oil-tankers, aeroplane parts, semi-conductors, video-tape recorders, colour television sets, micro-wave ovens, numerically controlled machines, cranes, excavators, and so on. These compositional changes have been accompanied by steeply rising employment, labour productivity, total factor productivity, real wage rates and skill and educational level of the labour force.

This paper aims to provide an explanation (or a set of hypotheses) for the rapid pace of industrial "deepening" which has been accomplished during the last 30 years. The main theme is to argue that technology learning has been an important driving force for Korean industrialization. A subsidiary theme is that technology learning and mastering innovation shall be even more important in the 21st century, as the Korean economy is preparing to join the OECD(Organization for Economic Cooperation and Development). By way of presentation, two questions are asked; (1) Where have the Korean technological capabilities come from? (2) What policies has the government formulated and what effects have they had? The exposition includes an assessment of the interplay between the government and market with a special focus on institution-building exercises, which tended to augment the market rather than repress it.

Chapter two discusses the macroeconomic environment in which Korean private enterprises (especially Chaebols) had to make decisions, take risks, compete and grow. Five sub-topics shall be discussed in the following order ; (1) Policies to upgrade industrial structure. Salient features of government policies, with direct and indirect impact on industrial structure and technological ladder climbing are reviewed ; (2) Building technology infrastructure and capability -reviewing the way in which the government has been involved in creating infrastructure for educating engineers, and also for generating and disseminating technological information ; (3) R&D manpower and industrial skills in private enterprises - observing the responses of private enterprises to the government efforts to entice them for risk-taking in R&D activities ; (4) Accumulation of human capital asset - noting the rapid growth in supply of educated manpower in the past, as well as a demand projection into the future.

Chapter three continues the discussion of technological growth in Korea particularly with respect to causal factors explaining productivity growth. The existing explanation of industrialization is briefly reviewed followed by the author's own hypothesis involving (1) accumulation of technological knowledge, (2) accumulation of education and training (i.e. human capital formation), and (3) institution building (e.g. crafting organizational devices). These factors individually are regarded as necessary conditions, and they collectively form a sufficient condition for productivity growth or, T.F.P(total factor productivity) gains in industry. Further, discussions ensue concerning "the Chaebol's role" as an institutional device for learning, as well as the Korean trade regime functioning as a national technological learning device.

Chapter four summarizes the implications of the Korean experience for development theory and policymaking.

Chapter 2 Research and Education in Korea : Building Technological Capability

South Korea has gone through six Five-Year Economic Development Plans since 1962. One of the major themes, common to all the documents, emphasized upgrading the industrial structure so as to sharpen the international competitiveness of South Korean industry. This means that each plan period envisaged a set of priority manufacturing sectors and projects. For instance, the 1970s saw the Development Plans targeting iron and steel, cement, fertilizer, chemicals and machines as priority sectors. Table 1 reviews the shifting emphasis and priority since the 1960s.

Table 1
Direction of Industrial Development and Technology Strategies

	1960s	1970s	1980s	1990s
Direction of Development	- Consolidation of Industrial Base - Selected Import Substitution - Expansion of Social Overhead Capital	- Industrial Restructuring toward Heavy Chemical Industries - Expansion of Social Overhead Capital	- Adjustment and Upgrading Industrial Structure - Development of System for Technology-Capability Building	- Realization of Advanced Industrial Society - Join the Group of Advanced Nation in Technology
Technology Strategies	- Establish Basis for Promotion of Science & Technology - Import Advanced Technology and Mastering	- Expansion of S & T Education - Improvement of Imported Technology	- Nurturing Brainpower for High Level S&T Development - Improved Application of Imported Technology - Core Technology Development	- Continuous Supply of High Quality Brainpower - R&D for Future Oriented Projects and Advanced High Technology Development
Leading Industry Sectors	- Textile Plywood Cement Fertilizers Electricity Oil-Refining	- Steel (Specialty Steel), Petrochemical, Ship-building Construction Shoes, Chemical Fiber, Electronics	- Electronics Parts, Computer Semiconductor General Machine, Automobile	- Information Industry, Advanced Materials, Bio Engineering Systems Engineering

Source : Korea Industrial Technology Association, Industrial Technology White Paper 1986 (in Korea) p.213

The record of plan implementation shows that the planned targets have usually been fulfilled or exceeded by wide margins in industrial output, export and investment. These achievements have been usually attributed to strategies that promote export. However, as the following sections show, import substitution or localization activities have also played an important role in bringing about an upgraded industrial structure and gains in productivity at the same time.

Various strategies were to serve the overriding objective of restructuring industrial composition. Both export-promotion and import-substitution policies must be understood in this larger framework. The shift to an export-oriented policy stance in the mid-1960s did not mean the discarding of import-substitution activities. Indeed, the latter went on along with the export-led strategy. Export expansion and import substitution were not contradictory activities but were complementary to each other. The expansion of export production required a corresponding increased demand for imported intermediate inputs, parts and machines. The policy makers were quick to notice the import substitution possibilities for these export-related imports.

The most serious concern and determination to launch a wholesale import substitution project came in the early 1970s when the rapid export growth brought chronic trade-deficit problems, especially with Japan. Technological ties with Japan meant that production for soaring exports required ever increasing imports of Japanese machineries, intermediate inputs and parts, while the major markets for Korean exports lay elsewhere, namely, in the United States, Southeast Asia and Europe.

The policymakers decided to correct the trade balance problem in part by producing at home, replacing imports from Japan and elsewhere. Apparently, policymakers realized that a general devaluation of the won alone, would not be able to correct the bilateral trade imbalance with Japan. Furthermore, shifting the policy orientation to a new product group provided an opportunity to "deepen the industrial base". In 1973 a "Heavy and Chemical Industry Development Plan" was announced to guide the expansion of heavy industrial sectors for the period of 1973-1981. A series of projects were formulated in priority sectors including iron and steel, nonferrous metals, petrochemicals, fertilizer, machinery, electronics and shipbuilding. These sectors represent Hirschman's backward-linkage import substitution to support labour-intensive export sectors in South Korea (except shipbuilding). The uninterrupted supply of these products from domestic sources, which were subject to less market volatility, was thought to be crucial for continued export-led growth.

Thus by upgrading the industrial base from light labour-intensive industries, by adding heavy capital and skill intensive industries, South Korea could solve several problems simultaneously: (1) other developing countries, with lower wage rates than South Korea, were increasing competitive pressures in the area of light industries; (2) South Korean wages were rising rapidly; (3) protectionism was threatening the future export prospects of South Korea. Another imperative need was to nurture defense-supporting industries for obvious reasons of geo-politics. Structural change has been an ongoing process largely due to these conditions.

With the 1980s, priority candidates for import substitution shifted to "engineering industries" from the "heavy and chemical" orientation in the 1970s. "Engineering Industry" is defined as assembly-type manufacturing plus parts production (SITC 381, 382, 282, 284 and 385) which produces capital goods or durable consumer goods (e.g., automobiles, colour TV sets, home appliances, VTRs, industrial machines, etc.).

As in the case of basic industrial materials in earlier periods(e.g., iron and steel, non-ferrous metals, petrochemicals, etc.), Korea's trade balance with Japan deteriorated again during the mid-1970s and early 1980s. This was due to heavy dependence on Japanese components and parts for the assembly manufacturing. The government initiated programme for "localization" of parts and component production, another wave of backward linkages, la Hirschman.

Table 2 provides sectoral shares of ISIC three-digit classifications for South Korean manufacturing for 1970 and 1986. The difference between these two years shows relative sectoral advances and lags in output structure. Striking is the fact that the so-called modern sectors, or engineering-intensive sectors, gained at the expense of traditional sectors (e.g., food, textiles, etc.). The leading sectors include Electrical Machinery (+17.5 percentage points), Transport Equipment (+4.29 percentage points), Non-electrical Machinery (4.18 percentage points), Iron and Steel (+3.56 percentage points), etc.

The flurry of investment activities has resulted in a quantum jump toward capital intensive technology, particularly for the "engineering industry" and heavy industry categories. For instance, the "Iron and Steel" sector registered 5,880 thousand won worthy of machinery and equipment per worker in 1963, but it grew to 61,688 thousand won in 1990 (all figures in 1985 constant price). Table 3 shows other sectors. It should be noted that every sector indicates a rapid shift toward a capital intensive technology, though with some difference in speed between sectors. If the fact of technology shift is considered along with the record of productivity gains, one could immediately realize (or hypothesize) how much "learning" must have been taking place for new ways of producing with new technology and building new concomitant organizational structure.

Table 2
Sectoral shares of Manufacturing Output
South Korea, 1970 and 1986

Manufacturing	Output share in		Change
	1970	1986	1970-1986
311 Food manufacturing	8.89	6.31	-2.58
313 Beverages	2.91	1.28	-1.63
314 Tobacco manufactures	1.04	0.29	-0.75
321 Textiles	13.57	8.99	-4.58
322 Wearing apparel	2.16	4.26	2.10
323 Leather and fur products	0.03	0.64	0.61
324 Footwear, excl. rubber/plastic prod.	0.72	0.84	0.21
331 Wood and wood products	2.86	0.49	-2.37
332 Furniture and fixtures	0.72	0.40	-0.32
341 Paper and paper products	2.27	1.93	-0.34
342 Printing and publishing	4.74	1.50	-3.24
351 Industrial chemicals	10.85	5.79	-5.06
352 Other chemical products	4.75	4.21	-0.54
353 Petroleum refineries	6.71	2.13	-4.58
354 Misc. petroleum and coal products	2.05	1.20	-0.85
355 Rubber products	2.38	2.72	0.34
356 Plastic products n.e.c.	2.42	1.63	-0.79
361 Pottery, china and earthenware	0.73	0.28	-0.45
362 Glass and glass products	2.14	1.10	-1.04
369 Other non-metallic machinery	7.41	3.59	-3.82
371 Iron and steel	2.96	6.52	3.56
372 Non-ferrous metals	0.61	1.67	1.06
381 Metal products excluding machinery	1.48	3.70	2.22
382 Non-electrical machinery	4.63	8.81	4.18
383 Electrical machinery	2.61	20.11	17.50
384 Transport equipment	1.76	6.05	4.29
385 Professional and scientific goods	0.66	1.01	0.35
390 Other manufactures	5.93	2.53	-3.40
300	100.00	100.00	
Total Output $million (1985$constant)	5,152	54,055	

Source : UNIDO database

Table 3
Machinery and Equipment Stock per Worker (in 1985 constant thousand won)

	1963	1970	1990	1980
1. Food	1,978	1,707	3,851	9,889
2. Beverage	1,360	1,342	5,938	21,262
3. Tobacco	2,139	2,645	2,803	24,872
4. Textiles	2,362	2,394	5,400	12,710
5. Apparel	853	511	857	1,137
6. Leather	941	1,606	3,145	4,205
7. Footwear	680	804	2,986	16,141
8. Wood	2,991	1,696	2,945	4,433
9. Furniture	375	400	760	1,997
10. Paper	3,942	4,250	7,027	14,506
11. Publishing	2,149	2,110	4,927	7,133
12. Ind Chem	30,688	17,340	19,204	59,378
13. Other Chem	1,005	1,437	4,886	13,147
14. Petrol Ref	-	21,937	80,375	53,268
15. Petro & Coal	911	1,805	3,613	9,588
16. Rubber	1,303	1,896	2,692	2,997
17. Plastic	7,789	2,034	3,452	5,772
18. Pottery	143	369	1,668	4,319
19. Glass	162	908	4,792	8,783
20. Non-Metal Min	7,839	6,298	12,220	33,867
21. Iron & Steel	5,880	6,644	28,665	61,688
22. Non-Ferr	3,679	5,791	12,719	19,091
23. Fabricated Metal	1,421	1,377	4,128	5,874
24. Machinery	1,706	2,618	10,000	15,371
25. Elect Mach	2,100	1,648	5,267	12,417
26. Transport eqpt.	2,645	3,356	9,699	17,994
27. Professional eqpt.	1,779	1,036	1,243	387
28. Other	840	350	1,726	3,040
29. Total	3,916	3,499	7,525	12,132

Source : Computed from basic data provided by Hark K. Pyo "A Synthetic Estimate of the National Wealth of Korea, 1953-1990", Korea Development Institute,(KDI Working Paper No. 9212) May 1992, and employment data by sector UNIDO databank

It can be argued, that the South Korean government has made substantial progress in its efforts to build various institutions in order to enhance the technological capabilities of industry. The rapid industrial progress achieved during the past three decades owes to government support in various forms designed to help private enterprises. The government took the initiative in building research institutes, facilities for educating and training scientists, engineers, and technicians, links between industries and universities, and so on. Furthermore, the government offered incentive measures in order to entice private enterprises into taking technological risks. This aspect of policy-making deserves special attention and analysis.

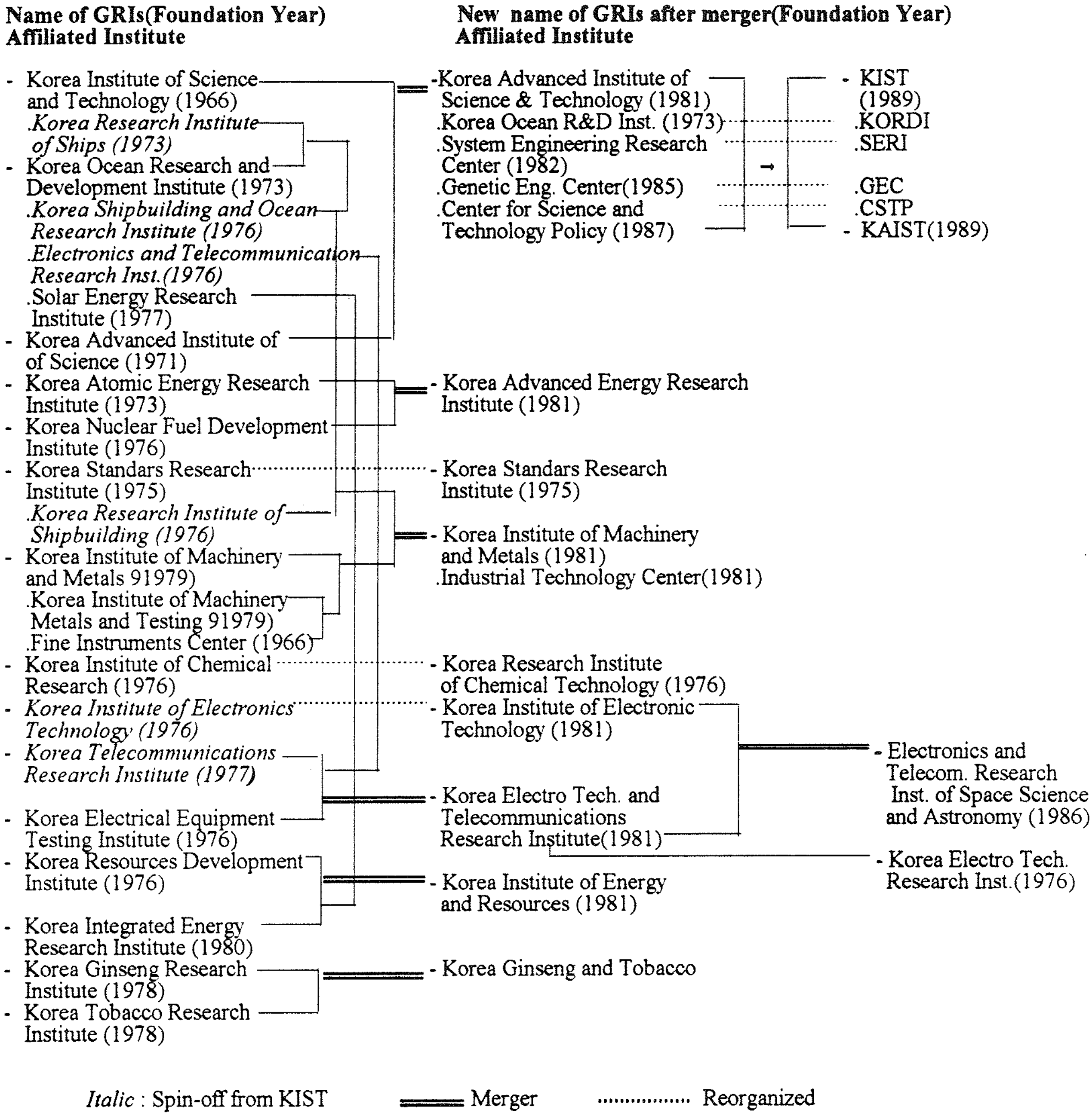
2.1 Building technology infrastructure and capability

The government started building the national infrastructure for research and development by establishing the Korea Institute of Science and Technology (KIST) as early as 1966. Initial organizational assistance for KIST came from the Battelle Research Institute of the United States.

Since then, the government has been continuously adding specialized R&D institutes to the national network of science and technology expertise. This is shown in Figure 1. As of 1990, these institutes were manned by 10,655 researchers.

An overall evaluation of the government-financed R&D system would appear to give it successful marks. An evaluation of the contributions made by KIST, so far are as follows. KIST : (i) has played a leading role in industrial technology development through over 5,600 research projects; (ii) established and developed R&D institutions through spin-offs and dissemination of R&D management systems; (iii) cultivated and disseminated more than 2,000 highly experienced R&D personnel; (iv) acted as the linch-pin "Think Tank" in the national R&D system supporting the implementation of national R&D policies and disseminating state-of-the art information; (v) offered support to S&T policy making thorough policy studies and technical feasibility studies; (vi) provided a Korean center of international technical collaboration through cooperative R&D programmes; and (vii) created a favourable climate for the advancement of science and technology by introducing over 12,000 new technologies to the public. (The source of this information is the same as Figure 1).

Figure 1
The Longitudinal Development Process of Government Financed Research Institutes in South Korea



Source : Dal Hwan Lee, Zong-Tae Bae and Jinjoo Lee, "Performance and Adaptive Roles of the Government-Supported Research Institute in South Korea," *World Development,* Vol.19, No.10 (1991), p.1425

The economies of developing countries have typically been characterized by weak links between government-financed R&D institutions and private enterprises. The South Korean system seemed to have initially suffered from a similar tendency. However, this tendency has been gradually overcome by special efforts and devices for network building.

For instance, the Korea Institute of Electronics Technology has close consultations with private enterprises, as its governance structure includes the latter. The board of directors consists of four representatives from government ministries, five from private producers of electronic goods, one from the Electronics Industry Association, one from universities, and one from the institute. Each of the three working-level groups under the board, (namely equipment programme, work programme and training programme) includes representatives from producers, the government and the institute.

Besides such institutional links, there are also human links between private enterprises and government-financed research institutes. Researchers in government institutes usually Ph.D. holders from U.S. universities have often been scouted by private enterprises, which offer attractive salaries and levels of responsibility. Furthermore, the Korea Advanced Institute of Science and Technology(KAIST), a part of the institutional edifice established in 1971, has been producing Ph.Ds and M.A.s to man the research units of private enterprises. So far the institute has produced over 1,584 Ph.D.s and 7,538 M.S.s. This source has provided core researchers for private enterprises, to add to the pool of graduates from universities in the country. It is worth noting that the academic standard for the KAIST Ph.D. degree, requires at least one publication in an established international journal. Furthermore, every student admitted to the Institute receives a full scholarship including tuition fee, room and board. Moreover, the graduates are exempted from compulsory military duty. These incentives attract the most qualified students in the country. The whole set-up reflects the top national priority placed on producing well-trained technical manpower to support the research and development skills needed for rapid industrialization.

Not only the supply of trained experts, but also the demand for them, seems to have been influenced by government activism. In order to help private enterprises upgrade their R&D capability, the government enacted the "Law for Technology Development Promotion" in 1972. The law defines incentive measures for R&D related investment such as tax exemptions, low interest loans, free information services on availability of advanced technology etc. Particularly notable is the legal requirement to establish an in-house research organization for enterprises with more than 500 employees. Private enterprises have accepted this requirement because of the pull of market forces. In 1964, there were only 13 research institutes owned by private enterprises. In 1972, there were 133; by 1990 the number grew to 1,718. Tables 4-7 show other technological capability indicators.

The number of export items, as shown in the last column of Table 7, deserves a special attention. In 1963, only 119 items were registered. By 1987, the number soared to 5,270 items. The rapid growth indicates that Korean firms have learned and mastered new technologies such that international markets have accepted the price and quality of the new products. Thus the number could serve as a performance indicator of technology learning. The building of infrastructure to link export., promotion and technological upgrading is explained in the next chapter.

The rapid export diversification and supportive technology learning was facilitated by continuous flows of scientists and engineers between sectors. For instance, private R&D organizations have scouted R&D staff often from government research institutes due to their high level of competence and connections that the new recruits will bring. These formal and informal connections seem important to facilitate information flows on matters pertaining to the technology market (e.g. supply and demand conditions for technological ideas). Such connections tend to alleviate the imperfections and failures of information market.

It is worth noting that initially, the government dominated in R&D expenditures - over 80 percent during the 1960s. But by 1990 the share declined to below 20 percent(See table 5). Private enterprises seem to have learned the importance of raising their technological capabilities in order to remain competitive in the international market.

But such awareness has been raised constantly by public campaigns sponsored by government agencies. Campaigns have apparently proven to be an effective instrument to disseminate information and to reach social consensus. For example, the contribution of the Korean Productivity Center(KPC) must be given a high score, although it has been little publicized. Established in 1957, it is one of the oldest institutions designed particularly for small and medium scale industries. Essentially, KPC provides "technological extension services" much like agricultural extension services for farmers. KPC has sponsored lectures, visitations for consultations, demonstrations, pilot projects and so on, all for the purpose of closing the productivity gap between small and medium industries and large-scale industries, which have been generally more technologically advanced. It is difficult to quantify the effects of KPC actions in any precise manner. But, a study has shown that total factor productivity has been growing faster in the small and medium industry sector than in the large-scale sector of manufacturing as measured throughout the 1970s.[1] This seems to have contributed to narrow the productivity gap between large producers and medium scale producers.

In the early 1980s, another institution was created to complement the KPC, the Korea Institute of Economics and Technology(KIET). The major aims of KIET consist of providing information on technology availability and overseas markets to domestic producers in small and medium industries. The institute functions also as the think tank for the Ministry of Trade and Industry, advising on industrial, as well as trade policy formulation. Its sectoral forecasting has been a helpful tool for private enterprises to plan ahead for production and export. The Institute is manned by over 400 specialists and researchers.

And finally but not exhaustively there is a unique Korean-style technology-boosting campaign, called the National Technology Promotion Conference, held four times a year. It was presided over by the President during the 1980s, but this is no longer in effect in the 1990s.

This conference has symbolized that building technology-capability received top national priority. It has been attended by 250 representatives from government agencies, industries,

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[1] See Jae-won Kim, "The rate of total factor productivity in small and medium industries and economic development: The case of Korea's manufacturing", in *Industry Development Policies and Issues*, edited by Kyu-Uck Lee, Seoul: Korea Development Institute, 1986, pp.131-160. There exists an elaborate system of assisting small and medium scale industries. For details see the Ministry of Commerce and Industry, *Annual Report on Small and Medium Industries*, 1994, Chapter 5

universities, research institutes, banks and the mass media. Its' purpose has been to examine and define strategies for technology development, R&D cum science, technology manpower development, productivity enhancement, and to disseminate information on international developments in high technology areas. The conference also reports on progress of domestic technology development projects, and on the direction of international competition and challenges facing South Korea. It has been a "ritual" akin to the "Presidential Conference for Export Expansion" during the 1970s; but these meetings seem to have functioned in Korea, to provide the tools and means for correcting market failures and imperfections, such as the prohibitively expensive cost of information on technology. In addition, fundamental uncertainties of technological risk-taking have often been reduced either by "fiat" or by "consensus" reached in the conferences. Furthermore, the conference has offered opportunities for collective learning as to how the technology factor should be managed at the industry and firm levels.

The National Technology Promotion Conference has also facilitated the management of the economic characteristics of the 'technology factor' which need to be taken into account in policy making. These characteristics include the externalities of public goods(that is one's use does not exclude another's concurrent use of technological knowledge), cumulativeness, irreversibility, history or path dependence, and dynamic increasing returns or the effect of learning-by-doing. Other characteristics include : the uniqueness of technology transactions, the lack of a market-determined price, and asymmetrical bargaining strength. To what extent the meetings have succeeded in addressing these problems, constitutes an important research agenda to be answered in years ahead.

2.2 R and D manpower and industrial skills in private enterprises

So far, a picture has been painted to describe how the government has been active in developing the infrastructure for building science and technology capabilities. This section presents some information indicating how private enterprises have responded to government initiatives. Upgrading the national techno-industrial base has involved innovative efforts by individual enterprises and the workers who man them. First, some observations will be made distinguishing different innovative behaviors between large enterprises and small to medium enterprises. Second, some general remarks will be made regarding the supply of educated manpower during the last three decades and its contribution to industrialization in South Korea.

In the process of technological upgrading in South Korea, the industrial conglomerates or Chaebol groups have played a leading role. Most notably in this respect is the product diversification of the Chaebol groups, as a strategy of "maximizing market share" and "empire building" at the same time. For that purpose, each group has been adding new products to their output and also to the export basket at a phenomenal speed. For instance, the Gold-Star Group started out with one item in 1949; added 8 items during 1950-1959; added again 25 items during the 1960-1969 period; added further 40 items during 1970-79; and added again 49 items during 1980-1984. For another example, Daewoo group started out with a single item, clothing, in 1967. By 1990, the group has exported over 400 items. The number of Chaebol groups has also rapidly multiplied from six in 1962 to 108 by 1984. The number can vary depending upon the definition of Chaebol. In any case, they all have competed in the product-diversification and the empire-building game.

Virtually without exception, the ability to produce new products and to export meant that new technologies were developed locally or imported. Either approach required the domestic capability of assessing technological needs and adapting imported technology or inventing to meet the needs. In short, private enterprises had to invest in R&D activities and training regardless of the technology sources.

The rapid growth of R&D institutes and the number of researchers in South Korea reflects such needs as shown in Table 4. Note that the numbers grew faster in the case of private companies than the national total. These increasing numbers reflect governmental pump-priming in science and technology promotion.

Private enterprises have learned to utilize various avenues of technology acquisition. Aquisition of technology has occurred not only by using in-house R&D but also from government research institutes through jointly constructed projects. In addition, private enterprises have exploited foreign sources by scouting top scientists and engineers from U. S. companies, inviting retired engineers as periodic consultants, or recruiting Korean-born scientists working at IBM, Hewlett-Packard, General Electric, and so on. Other avenues have included establishing research outposts in the Silicon Valley and joint venture projects with foreign firms. The large wealth accumulated within Chaebol groups enables them to venture into high technology areas where initial R&D investment requirements are prohibitive for small to medium enterprises.

Table 4
Number of Research Institutes and Researchers
in South Korea, 1964-1990

Year	R&D performing institution		Number of researchers	
	Total number	Private companies	Total number	Private companies
1964	87	13	1,906	n.a.
1965	105	22	2,765	n.a.
1966	108	22	2,962	n.a.
1967	223	98	4,061	n.a.
1968	273	100	5,024	n.a.
1969	280	104	5,337	n.a.
1970	297	107	5,628	1,159
1971	305	118	5,320	925
1972	319	133	5,599	1,149
1973	368	167	6,065	1,405
1974	456	242	6,314	2,552
1975	553	303	10,275	2,655
1977	626	278	11,661	3,258
1978	647	291	14,749	4,304
1979	641	305	15,711	4,405
1980	647	321	18,434	7,165
1981	662	323	20,718	7,165
1982	860	554	28,448	9,959
1983	1,080	742	32,117	12,586
1094	1,143	782	37,103	15,914
1985	1,291	928	41,473	18,996
1986	1,682	1,321	47,042	22,915
1987	1,865	1,478	52,783	26,104
1988	2,821	1,633	56,545	28,299
1989	2,077	1,689	66,220	35,167
1990	2,105	1,718	70,503	38,737

Source : Ministry of Science and Technology, *Science and Technology Yearbook* (Annual)

Besides the efforts to acquire and master new technologies, private enterprises have been sharing the costs of training production workers in a significant manner. In advanced industrial countries, one finds a variety of arrangements. Japan's system of life-long and intensive in-plant training and the American system of "outside training" including vocational schools before employment are two approaches. It is well known that in the latter system the workers' freedom to leave a job discourages enterprises to spend resources for training employees -negative externalities.

In order to address such negative externalities or the free-rider problem as it is often called, the South Korean government enacted the "Vocational Training Law" in 1966. The law was "strengthened" at the advent of the Third Five YearPlan (1977-81) by introducing a compulsory training programme requirement. The government saw that the market would not respond quickly enough to supply the required number of technicians and skilled and semi-skilled manpower in order to carry out the five year plan. This incidence provides an example of the policymakers' philosophy at the time - namely, if the market was expected to be slow in responding or flawed because of fundamental market failure phenomena, then the government was ready to selectively bypass market mechanisms.

Table 5
R and D Expenditures in South Korea, 1963-1990

Year	R&D expenditures		
	Total (Unit : 100 million won)	Government ratio (%)	Non-Government ratio (%)
1963	12	-	-
1964	14	96.4	3.6
1965	21	89.9	10.1
1966	32	89.9	10.1
1967	48	83.6	16.4
1968	67	85.2	14.8
1969	98	81.8	18.2
1970	105	71.3	28.7
1971	107	72.2	27.8
1972	120	68.1	31.9
1973	156	55.6	44.4
1974	382	65.7	34.3
1975	427	66.7	35.3
1976	609	64.8	35.2
1977	1,083	47.7	52.3
1978	1,524	48.8	51.2
1979	1,740	54.5	45.5
1980	2,117	51.6	48.4
1981	2,931	43.6	56.4
1982	4,577	41.3	58.7
1983	6,217	27.5	72.5
1984	8,339	21.4	78.6
1985	11,552	19.5	80.5
1986	15,233	19.1	80.9
1987	18,780	20.4	79.6
1988	23,747	17.7	82.3
1989	28,173	20.4	79.6
1990	33,499	19.4	80.6

Source : Ministry of Science and technology, *Science and Technology Yearbook* (annual)

Table 6
Researchers by field of science and degree in South Korea, 1988

Field of science	Total	Doctor	Master	Bachelor	Others
Total	56,545	13,419	17,374	24,240	1,512
Natural science	8,665	3,691	2,664	2,277	33
Mathematics	1,157	621	341	193	2
Physics	1,584	708	454	410	2
Chemistry	3,004	1,004	834	1,153	13
Earth and space	445	236	126	81	0
Biology	1,371	732	375	259	5
Others	1,104	389	528	181	11
Engineering	34,153	4,432	9,545	19,150	1,026
Machine, ship and airplane	8,876	748	1,970	5,783	375
Materials	2,660	596	819	1,217	28
Electricity and electronics	11,993	990	3,381	7,232	390
Chemical	4,208	632	1,035	2,460	81
Food and genetic	1,518	325	483	695	15
Textile	667	116	179	353	25
Atom	300	94	129	77	0
Natural resource	196	80	58	55	3
Construction	2,144	558	833	692	61
Others	1,591	293	664	586	48
Medical,pharmaceutical,health	6,673	3,342	2,308	978	45
Medical	4,574	2,814	1,270	489	1
Pharmaceutical	1,020	367	288	364	1
Health and nurse	888	123	667	79	19
Others	191	38	83	46	24
Agricultural,forestry,fishery	4,415	1,576	1,487	1,161	191
Agriculture and forest	3,861	1,450	1,293	983	135
Agriculture and forest	3,000	1,101	1,050	728	121
Animal and dairy	599	228	160	200	11
Others	262	121	83	55	3
Fishery and ocean	554	126	194	178	56
Others	2,639	378	1,370	674	217

Source : Ministry of Science and Technology, as reported in Korea Industrial Research Institute, *Major Indicators of Industrial Technology* 1990, Seoul, August 1990, p.131.

Table 7
Inicators of technological capability - South Korea, 1963-1990

Year	Number of technology imported	Number of patents applied		Number of patents granted		Capital goods imported (million dollars)	Number of export items at CCCN 8-digit*
		Total	To Korean nationals	Total	To Korean nationals		
1963	3	n.a.	n.a.	n.a.	n.a.	n.a	119
1964	1	908	n.a.	n.a.	n.a.	n.a.	142
1965	4	1,018	n.a.	n.a.	n.a.	n.a.	350
1966	18	1,060	n.a.	n.a.	n.a.	172	445
1967	36	1,177	n.a.	n.a.	n.a.	310	513
1968	51	1,463	n.a.	n.a.	n.a.	533	650
1969	59	1,699	n.a.	317	n.a.	593	822
1970	92	1,846	n.a.	266	n.a.	590	952
1971	47	1,906	n.a.	229	n.a.	685	983
1972	53	1,995	n.a.	218	n.a.	762	1,002
1973	67	2,389	n.a.	199	n.a.	1,159	1,059
1974	88	4,455	n.a.	322	n.a.	1,849	n.a.
1975	99	2,914	n.a.	442	n.a.	1,909	n.a.
1976	127	3,261	n.a.	479	n.a.	2,427	n.a.
1977	168	3,139	1,177	274	104	3,008	n.a.
1978	297	4,015	994	427	133	5,080	n.a.
1979	291	4,722	1,034	1,419	258	6,314	n.a.
1980	222	5,070	1,241	1,632	186	5,125	n.a.
1981	247	5,303	1,319	1,808	232	6,158	4,356
1982	308	5,924	1,556	2,609	274	6,233	4,401
1983	362	6,394	1,559	2,433	245	7,851	4,434
1984	437	8,633	2,014	2,365	297	10,106	4,773
1985	454	10,587	2,703	2,268	349	11,079	4,850
1986	517	12,759	3,641	1,894	458	11,340	5,142
1987	637	17,062	4,871	2,330	596	14,552	5,270
1988	751	20,051	5,696	2,174	575	19,033	
1989	763	23,315	7,021	3,972	1,181	22,370	
1990	738	25,820	9,082	7,762	2,554	25,545	

Source : Ministry of Science and Technology and Ministry of Trade and Industries.
* Note : Refering to the last column, the use of CCCN classification was discontinued in 1988

2.3 Accumulation of human capital assets

Human capital has been increasingly recognized as a crucial element in industrial development. Intuitively, the need for an educated and well-trained labour force is obvious. However, theory has not been sufficiently developed to yield policy guidance as to the optimum level of investment in human capital formation. The reason seems to be the complexity of relevant variables and their interactions (e.g. education externalities)[2] as well as measurement problems for empirical testing. Nevertheless, it seems to be widely accepted that the high economic performance of the Asian NICs(Newly Industrializing Countries) owe very much to a well-educated and well-trained labour force.[3] In this section, some salient aspects of human capital formation in South Korea are presented, and future implications are considered.

The first feature to be noted is the rapid increase in the supply of educated manpower, as a percentage of total new employment figures every year ; table 8 shows the share of college graduates, junior college graduates, high school graduates, and junior high graduates. finding new employment in the economy since 1973. It should be noted that the proportion of high school graduates soared from 16 percent in 1973 to 56.3 percent in 1992. The total sum of high school, junior college and college graduates jumped from 20.9 percent in 1973 to 72.1 percent in 1992. The latter figure seems significant, as researchers found that productivity gains are most significantly correlated with the share of high school graduates in the labour force. [4]

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[2] Theodore Schultz advances the idea that human capital has external effects. "These effects spill over from one person to another. People at each skill level are more productive in high than in low human capital environments. Human capital enhances the productivity of both labour and physical capital...". Quoted from Theodore Schultz, *Restoring Economic Equilibrium - Human Capital in the Modernizing Economy* (Oxford, Basil Blackwell, 1990), p.215.

[3] A concise summary of the literature on this issue can be found in K. Gannicott "The Economics of Education in Asian-Pacific Developing Countries", *Asian Pacific Economic Literature*, Vol.4, No.1 (March 1990), pp.41-64

[4] See William J. Baumol, Sue A.B. Blackman and Edward N. Wolff, *Productivity and American Leadership : The Longrun View* (Cambridge : The MIT Press, 1989) p.206

Table 8
Proportion of Educated Workers Acquiring Employment
1977-1993 (%)

	Whole Industry	Elementary School Graduates	Middle School Graduates	High School Graduates	Junior College Graduates	College Graduates
1973	100	44	35	16	0.9	4.1
1974	100	41	36	18	1.1	4.3
1975	100	36	40	19	1.1	4.4
1976	100	32	42	19	1.2	5.2
1977	100	30	40	22	1.3	5.9
1978	100	28.1	42.7	22.1	1.3	5.7
1980	100	22.6	46.4	23.0	1.7	6.0
1981	100	18.8	45.1	26.5	1.9	7.6
1982	100	16.9	44.4	31.1	2.5	5.0
1983	100	13.5	44.4	34.1	2.8	5.1
1984	100	12.2	43.3	37.1	2.8	4.5
1985	100	10.7	42	39.5	2.9	5.0
1986	100	8.9	37.2	45.4	3.2	5.2
1987	100	8.5	34.4	47.6	3.6	5.7
1988	100	7.3	32.2	50.1	3.9	6.3
1989	100	7.2	28.3	50.9	4.8	8.7
1990	100	7.6	25.4	52.7	5.5	8.6
1991	100	7.6	22.2	53.9	6.4	9.6
1992	100	7.2	20.5	56.3	6.3	9.5

Source : Korea Statistical Yearbook (annual 1977-1993)

An alternative interpretation for the same phenomenon is the finding that human capital stock exceeded physical capital stock during the 1960s when industrialization took off, as follows;[5]

	Stock of human Capital (million won) (A)	Stock of physical Capital (million won) (B)	(A) (B)%
1960	3,854,891	3,469,638	111.1
1966	6,390,643	4,324,254	147.8
1971	8,919,764	7,147,438	124.8

This gives a contrast to the ratio (A)/(B) for the United States : 43.5 per cent in 1929 and 66.8 per cent in 1957.[6] Based on this data, one could put forward the hypothesis that the rapid pace of industrialization is a result of the abundance of an educated labour force.

The second feature to be noted concerns a glaring mismatch between supply and demand for

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[5] Chang Young Jung (of Yonsei University), "Human Resources in the Korean Economic Development", a paper presented at the "Multi-Disciplinary Conference on South Korean Industrialization" held at the University of Hawaii, 14-17 June 1977. Human capital stock was estimated mainly on the basis of educational and training expenditures by households and the government. Expenditures on health are not included.

[6] Theodore W. Schultz, "Human Capital : Policy Issues and Research Opportunities" in *Human Resources*, Fiftieth Anniversary Colloquium VI, National Bureau of Economic Research, New York, 1972.

college graduates - a chronic oversupply for more than 20 years since 1965. This phenomenon has been attributed to the following influences : the emphasis on a high level of education in Confucian cultures; the preference for white-collar occupations which are conferred only on college graduates; and the high level of remuneration in white-collar occupations.

Kim[7] has stated : "For example, in 1986 college graduates' average wages were 2.2 times that of high-school graduates, and the average entry wage of high-school graduates tended to be below 70 percent that of college graduates."

The question whether the oversupply of college graduates represents a mismanagement of capital resources in the long-run remains controversial. In spite of this oversupply, the estimated social rate of returns was, 13.8 percent in 1977 compared with 9.9 percent for high-school graduates and 2.8 percent for middle-school graduates. In the same year, the employment of college graduates totalled 22,087, while universities and colleges produced 37,374 - an excess supply of over 15,000, indicating a significant degree of labour market disequilibrium and imperfection. The excess supply situation disappeared after the mid-1980s, and according to recent projections, a shortage of college-educated manpower is expected to occur in the 1990s (see table 9). Nevertheless, it could be argued that the abundance of college graduates, and human capital in general, has been a crucial factor enabling the economy to climb the technological ladder at a rapid pace, and hence ultimately to achieve productivity growth.

Table 9
Population by level of education in the Republic of Korea: 1980-2000
(Unit: 1,000 persons)

	1980	1990	2000
Population aged 14 and over	24,848 (100)	32,385 (100)	37,823 (100)
High school graduates	4,383 (17.6)	8,174 (25.2)	11,102 (29.3)
College students	721 (2.9)	1,787 (5.5)	2,213 (5.9)
College graduates	1,329 (5.4)	3,877 (12.0)	7,551 (19.9)

Source : Se-il Park, "Labour issues in Korea's future", *World Development,* vol.16, No.1(1988),p.104.

Indeed, the composition of college and university student enrollment is revealing as shown in Table 10. Note that the number of natural sciences and engineering students has been increasing faster than others. In contrast, in 1945, just before the Japanese occupation in Korea ended, the college and university system was serving primarily Japanese residents in Korea with a nominal quota for Koreans; "only 800 Koreans had graduated of which 300 were from the Medical School and about 40 from the School of Science and Engineering".[8]

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[7] Young-Chul Kim, "Survey report - Republic of Korea", in *Educated Unemployment* in Asia, Hiromitsu Muta(ed.), Tokyo : Asian Productivity Organization, 1990, p.264.

[8] Kunmo Chung, "Science and Technology and Development of Korea : phase-one report, Korea Science and Technology Policy Instruments Project" (Seoul, Korea Advanced Institute of Science and Technology, 1973), p. 21.

Table 10
Enrollment at third level institutions by field of study, 1965-1990
(selected years)

	1965	1970	1975	1981	1985	1990
Humanities	21,674	19,685	23,529	68,459	150,141	186,164
Education	21,339	27,932	45,212	68,300	94,796	
Fine arts	7,567	7,746	12,351	23,976	53,177	69,029
Law	6,789	6,006	6,218			67,839
Social sciences	27,135	36,821	37,247	123,942	257,738	286,814
Natural sciences	12,495	17,090	17,022	45,535	336.624	419,891
Engineering	26,929	49,784	73,743	134,376		
Medical sciences	12,256	19,332	29,248	25,679	39,408	40,430
Agricultural sciences	14,452	17,039	27,436	27,227		
General			25,213	10,915		
Total	141,636	201,436	297,219	535,876	931,884	1,070,167

Source : Minsitry of Education (South Korea)
Note : For 1985 and 1990 the numbers for natural sciences and engineering were combined.

Furthermore, Korean tradition valued the fields of medicine, law and social sciences more than engineering - a legacy of Confucian teaching with its emphasis on literati activities. Making one's hands greasy and dirty was looked down upon since the days of the Yi Dynasty. Following the Japanese occupation in 1910-1945, it took two decades of a (persistent) government campaign since 1945 for the promotion of science and technology before Korean values concering professions began to change.

2.4 Summary

The government has been active since the early 1960s in order to upgrade the techno-industrial base of South Korea. Three important elements have been noted, namely, technology acquisition and its mastery, human capital accumulation through education and training and institution-building, particularly for science and technology. These elements characteristically are not mediated by a well-functioning price mechanism. Indeed market failures are increasingly being recognized in the areas of technology, human capital and institutions.[9]

The government activism can be interpreted to have contributed to redressing market failures and imperfections. An additional interpretation can be advanced that institution-building government activism - in the South Korean way - represents market-augmentation rather than market-repression. Here, market-augmentation refers to encouraging the expansion of production and technology capabilities of enterprises. The aim has been to increase competitiveness in international markets via productivity improvement. This remains a hypothesis to be tested rigorously.

[9] For instance, see Giovanni Dosi, Keith Pavitt and Luc Soete, "Markets, institutions and technical change in open economies : some policy implications", in The *Economics of Technical Change and International Trade*, ed. by G. Dosi, et al, Harvester Wheatsheaf, Hertfordshire (England), 1990, chapter 8.

A question arises - what sort of evidence do we have to support the hypothesis? As an answer to the question, indirect (but suggestive) evidence-a measurement of Total Factor Productivity (TFP) commonly known as the Solow Index can be presented. Table 11 presents an estimate of TFP by 28 manufacturing subsectors for the 1966-1985 period (and for some sub-periods). Note that manufacturing as a whole has achieved 5.96 per cent annual TFP growth for the 20 year period-not a mean record. It is also worth noting that the engineering sectors (e.g. electric and non-electric machinery and transport equipment) scored a rather high rate of TFP growth.

Looking at sub-periods, a negative TFP growth is observable for total manufacturing for the 1971-75 period. Obviously, the first oil crisis must have had a negative impact through the lowering of capacity utilization.

The 1976-1980 period saw double digit TFP growth rates for metal products, non-electrical machinery, electrical machinery and transport equipment. If these estimates are valid, the negative assessment of the Heavy and Chemical Investment Programme(1973-1980) should be re-examined.[10] Learning here is a long-term proposition spanning a 10 to 20 year period.[11] The earlier the learning starts the better it is. Looking back from today's(1995) vantage point the programme could have beneficially started even earlier than it did.

The evidence reviewed so far suggests that a tremendous amount of "learning" has been accumulated. Regardless of whether a technology is imported or invented, it has to be "mastered" through practice. Consequently, it has to be "embodied" in individual workers and engineers, in the factory-system as well as in the national institutions. Such learning has provided the basis for industrial restructuring toward a higher level on the "technological ladder". The competitiveness of Korean industry is expected to be continuously strengthened in the future, so long as the learning habit and productivity move ahead of wage-and-salary growth.[12]

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[10] It has been alleged that too ambitious a push toward heavy and chemical industries (against Korea's comparative advantage) distorted resource allocation, and brought about a slowdown in growth as a consequence as well as the suppression of banking sector development. See Ji Hong Kim, "Korean Industrial Policy in the 1970s: The Heavy Chemical Industry Drive", KDI working Paper No. 9015, Seoul, July 1990.

[11] Staffan Jacobsson, "The Length of the Infant Industry Period : Evidence from the Engineering Industry in South Korea," *World Development*, Vol.21, No.3 (1993), pp.407-419

[12] Available statistics indicate that wage rates grew at an annual average of 8.5 percent while labour productivity grew by 10.9 percent during the past 20 years.

Table 11

Annual average TFP (Solow Index) growth rates in South Korean manufacturing, 1966-1985

Sector	ISIC Code	1966-1985	1966-1970	1971-1975	1976-1980	1981-1985
1 Food	311/12	7.3	21.4	-2.7	11.8	1.8
2 Beverages	313	7.9	22.9	6.0	-0.0	5.7
3 Tobacco	314	13.4	30.1	3.6	24.8	-1.5
4 Textile	321	10.7	16.6	11.5	9.5	6.5
5 Leather	323	12.6	2.9	39.0	-8.0	14.3
6 Wood and cork	331	9.4	13.7	11.3	2.0	11.5
7 Furniture and fixtures	332	12.1	2.1	7.7	28.5	8.0
8 Paper	341	8.2	11.7	3.8	13.1	4.9
9 Printing and publishing	342	10.7	14.7	-0.8	22.4	7.5
10 Chemicals	351/52	13.1	39.5	6.4	10.3	1.7
11 Petroleum and coal	353/54	-0.3	21.4	-11.5	-8.5	1.7
12 Rubber	355	11.4	17.4	8.2	23.0	-1.8
13 Earthenware and non-metals	361/62/69	2.8	-3.9	6.4	4.9	2.7
14 Iron and steel and metals	371/72	3.7	-0.7	0.0	5.8	8.7
15 Metal products	381	7.6	8.1	1.6	11.7	9.2
16 Non-electrical machinery	382	8.0	-0.3	9.0	12.5	9.3
17 Electrical machinery	383	10.7	15.7	3.4	16.4	8.5
18 Transport equipment	384	11.2	21.7	-2.6	18.4	9.6
19 Other manufactures	390	7.5	27.8	-8.9	8.1	7.3
Total manufacturing	3	5.8	15.3	-1.1	5.4	5.7

Source : Author's computation based on industrial statistics from UNIDO databank and capital stock estimates from Hak-Kil Pyo, Estimates of Capital-Output Coefficients by Industries for the Republic of Korea (1953-1986), KDI Working Paper No. 8810, Seoul,September 1988.

Chapter 3 Toward constructing a hypothesis for the Korean experience

In the foregoing chapter, some salient facts have been presented including the fast pace of structural change in output and employment compositions in the manufacturing sector along with achievements in education, R&D activities and productivity growth. An attempt is made in this chapter to review briefly some existing views on how to explain the Korean case. This includes the author's own view that a synthesis of diverse explanations would be necessary in order to make the resulting hypothesis useful, particularly for policymakers.

The traditional World Bank view asserted that the Korean experience can be explained by the neoclassical logic of outward-looking, free-trade philosophy. Bela Balassa, Anne O. Krueger, and Deepak Lall, belong to this school.[13] Their argument is based on the Walrasian general equilibrium theory. Free-trade policy has led the Korean economy to achieve higher values from given limited resources and therefore facilitating faster economic growth. This argument is also thought applicable to the cases of other Asian NICs(i.e., Taiwan, Hong Kong and Singapore). In addition, Latin American and South Asian import-substitution approaches (e.g. in Brazil and Mexico during the 1980s) would seem to provide a broad confirmation of the free-trade argument, as their growth rates faltered under the inward-looking trade regime. It follows that less government intervention and opening up of the economy to world trade would provide the best development policy. Such has been the World Bank stance, though it has been a somewhat oversimplified summary, until very recently.[14]

Theoretical elegance notwithstanding, the neoclassical stance, as traditionally advocated, seems inadequate to explain some real observation. Among others, the rapid shift of the Korean industry from an unskilled labour-intensive structure toward a capital intensive, a skill intensive, and possibly soon an information intensive, structure would seem to require some supplementary explanation. It is true that initially, the export orientation for unskilled labour intensive goods provided the major driving force for rapid industrialization, la comparative advantage theory which is consistent with the neoclassical theory. But, it is also true that the government followed a "selective import-substitution policy", though with varying emphasis and intensity, throughout the last three decades. An outstanding example is given by the case of the Pohang Steel Complex.

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[13] Balassa, Bela, "Exports and economic growth: further evidence," *Journal of Development Economics*, Vol.5, No.2 (June 1978), pp. 181-189
Krueger, Anne O., "Asian trade and growth lessons," *American Economic Review*, Vol.80, No.2 (May 1990), pp. 108-112
Lal, Deepak, *The Poverty of Development Economics*, Hobart Paperback 16, London: Institute of Economic Affairs, 1983

[14] In 1993, the World Bank has published a book entitled *The East Asian Miracle : Economic Growth and Public Policy*, Oxford University Press, 1993, where the Bank has revised its stance admitting that the role of government in the Asian NICs has been positive repairing market failures and imperfections. Earlier, some neoclassical economists advocated even a roposition that had the government been less interventionist than actually was, the South Korean economy would have grown even faster than recorded. Pure logic of economics could lead to such a far-fetched conclusion unless tempered by more down-to-earth realism. The assumption of an efficient market mechanism in existence would seem misleading as the experience of former U.S.S.R and Poland apparently demonstrate.

According to the traditional static comparative advantage theory, the Complex should not have been started initially. Indeed, a history book on the Complex recorded the reason why the World Bank refused a loan application from the South Korean government.[15]

The country lacked iron ores, coking coal, knowledge of steel making, and engineers needed for steel making and sufficient domestic market demand to satisfy the scale economy condition. A benefit-cost ratio proved to be less than one, a perfect economic logic for rejection. Today, however, the Complex is regarded as one of the most efficient steel producer in the world market.[16] Learning or mastering of new technology must be brought in as the central factor, if the Korean case is to be explained adequately.

Recent amendment to the neo-classical approach is propounded by those who believe technology-mastering is a crucial factor in explaining rapid industrialization, with productivity growth. Prominent writers in this school include Howard Pack and Larry Westphal, Christopher Freeman, Henry Bruton, Giovani Dosi, Linsu Kim and Jinju Lee.[17] They argue that technology learning and diffusion can be promoted by a set of policy measures, including temporary protection on a selective basis. Thus, the productivity of labour and capital can be raised.

Acquiring technological capabilities is a complex phenomenon, often defying operational conceptualization and measurement. Major difficulties are identified to include tacitness, sequentiality cumulativeness, non-reversability, externalities, information asymmetry, etc. The skill and effectiveness of managing these complexities seems to provide an important determinant of technology-mastering and diffusion, leading to productivity growth. Having studied the Korean experience, Pack and Westphal argue that "trade considerations are secondary to technological ones in searching for an understanding of industrialization that is relevant to policy making." [p.91]

There is still another school of dissent to the neo-classical interpretation of South Korean achievement, a group emphasizing the institutional aspects of industrialization. This group includes

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[15] In 1969 IBRD refused to finance the Korean project for building steel complex on grounds of its economic non-viability and Korea's inability to repay the loan. See POSCO, *A 20 year History of Pohang Steel Company* (in Korean) POSCO, 1989, PP.135-137

[16] For an excellent account, see Anthony P. D'Costa, "State, Steel and Strength : Structural Competitiveness and Development in South Korea" *Journal of Development Studies*, vol.31, No.1, October 1994, pp.44-81. The importance of having an efficient steel industry for downstream industries such as automobile, ship-building, machinery, construction etc cannot be over-emphasized. These have also emerged as competitive export industries during the 1980s.

[17] Pack, Howard, and Larry E. Westphal, "Industrial Strategy and Technological Change: Theory versus Reality," *Journal of Development Economics*, Vol.22, No.1 (June 1986), pp.87-128
Bruton, Henry, "Import Substitution," in *Handbook of Development Economics*, vol.II, edited by H. Chenery and T.N. rinivasan, Elsevier Science Publishers, New York, 1989
Kim, Linsu, "Science and technology policies for industrial development," paper presented at KDI/EDI Seminar on Korea's Experience in Trade and Industry Development: Its Relevance for Latin America, Seoul, Korea, 24 November - 2 December, 1986
Lee, Jin-Ju, *Policy Issues and Technological Innovation Process in Industrial Sectors* (in Korean), Korea Advanced Institute of Science and Technology, Seoul, 1986
Freeman, Christopher, *Technology Policy and Economic Performance : Lessons from Japan*, London, Pinter Publisher, 1987
Dosi, Giovanni, et.al., *The Economics of Technical Change and International Trade*, London, Harvester Wheatsheaf, 1990; and also G. Dosi, "Sources, Procedures, and Microeconomic Effects of Innovation," *Journal of Economic Literature* September 1988, vol.26, No.3, pp.1120-1171

Alice Amsden, Shahid Alam, Chalmers Johnson, Chung H. Lee, and Douglas North.[18] They discard the assumption of the perfect market and embrace the notion that government has an important role to play in repairing market failures and imperfections with continuous calibration of market, as well as non-market institutions, sometimes by creating makeshift arrangements. For example, Amsden opines that "Getting prices wrong" served as a policy tool to provide an incentive for private enterprises to take risks (e.g. subsidized interest loans).

In the author's view, each interpretation carries some important truth, although only a partial truth. They can be synthesized and, by doing so, useful policy implications can be extracted. The major factors, technological knowledge accumulation, human skills, and institution building, are complementary. Structural changes in industry can be explained more fully only when the interactions of the major factors are analyzed.

3.1 An Outline of Hypothesis - A formal expression

This section attempts to provide a hypothesis to explain the structural or compositional change, as driven by technological learning. Three factors are assumed to be important determinants of technological learning - namely, technological information or knowledge, human capital accumulation, and organizational or more broadly institutional devices.

The conventional theory has assumed that output is a function of capital and labour such that :

$$Q = F(K, L) \quad \text{..........(1)}$$

where Q is output, K, physical capital and L, labour. A specific form of this function is often represented by the Cobb Douglas production function :

$$Q = AK^{\alpha}L^{(1-\alpha)} \quad \text{..........(2)}$$

where A is a coefficient indicating a level of technology capabilities and i ≡, the capital share. Equation (2) implies,

$$\frac{\partial Q}{Q} = \frac{\partial A}{A} + \alpha \frac{\partial K}{K} + (1-\alpha)\frac{\partial L}{L} \quad \text{..........(3)}$$

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[18] Alam, Shahid, *Governments and Markets in Economic Development Strategies: Lessons from Korea, Taiwan, and Japan*, Praeger Publisher, New York, 1989
Amsden, Alice, *Asia's Next Giant: South Korea and Late Industrialization,* Oxford University Press, Oxford, 1989
Johnson, Chalmers, "Political institutions and economic performance: the government-business relationship in Japan, South Korea and Taiwan Province", in R.A. Scalapino et al.(eds), *Asian Economic Development - Present and Future,* Berkeley : Institute of East Asian Studies, University of California, 1985
Lee, Chung H., "The government, financing system, and large private enterprises in the economic development of South Korea," *World Development*, Vol. 20, No.2 (February 1992), pp 187-198
North, Douglas C., *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge, 1990

as expressed in growth rates of inputs and output. Applying time series data, one could estimate the growth rates of the technology level index.

The hypothesis advanced in this paper can be expressed as :

$$Q = F (K, L, T, H, O) \quad ....(4)$$

where T is technological knowledge, H, human capital, and O, organizational (institutional) skills (or devices). The last three factors determine the technological capabilities, A.

Thus, the revised Cobb-Douglas production function may take the following form :

$$Q = A (T, H, O) K^{\alpha} L^{(1-\alpha)} \quad ....(5)$$

Further, our hypothesis could include the following conditions of input-factor complementarities:

$$\partial^2 Q \;/\; \partial T \partial H > 0 \quad ....(6)$$
$$\partial^2 Q \;/\; \partial H \partial O > 0 \quad ....(7)$$
$$\partial^2 Q \;/\; \partial T \partial O > 0 \quad ....(8)$$

The following interpretation can be offered for these inequalities. Equation (6) states that technology(T) and human capital(H) are complementary to each other so that an increment of T and H would produce synergy effects on output(Q). For example, in digital technologies education in mathematics, information science and engineering sciences plus practical training are needed. Likewise, the equation (7) states that human capital can be organized so as to elicit its highest potentials in technical progress by devising a proper incentive system capable of motivating human capital owners (e.g. engineers, R&D personnel, etc). Equation (8) can be interpreted as saying that technological knowledge can be embodied in an organization or enterprise) as rules, norms, reflexes and habits. Nelson and Winter likened them to human genes, and they are capable of "mutations" through "organizational learning".[19]

3.2 Accumulation of Technological Knowledge

At the firm level, there is a variety of channels through which new knowledge can be obtained and learned :

(1) joint ventures with foreign companies
(2) installing new (imported) capital goods
(3) training or sending managers and workers abroad

[19] See Richard Nelson and Sidney Winter, *An Evolutionary Theory of Economic Change,* The Belknap Press of Harvard University Press, Cambridge, Mass., 1982, Chapter 5.

(4) hiring key engineers from other companies
(5) reverse engineering
(6) designing
(7) imitating (benchmarking)
(8) exporting through OEM(original equipment manufacturing) arrangement
(9) investing abroad
(10) purchasing licences

There may be other ways to learn beside those mentioned. However, the point here is that it is virtually impossible to quantify precisely the effect of all these learning sources and link such measurement directly with productivity growth.

However, C.K. Kim and B.T. Cho have recently estimated "R&D capital stock" for Korea covering the 1977-86 period. R&D capital stock was estimated on the basis of expenditures on purchases of machines and equipments, buildings and land, services, plus payments to employees (researchers and research support personnels), all connected with research and development of private enterprises and government R&D institutes. In the absence of any better measurement, their results must serve as a proxy for growing knowledge acquisition. (Refer to Tables 12-a, 12-b, 12-c. Several features can be noted immediately.

Table 12-a

R&D Capital Stock Estimated for Manufacturing Sub-Sectors 1977-1986 (at 1980 constant prices)

(Unit: 1980 Constant Million Won)

Industries ↓	Year →	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Food Processing(31)	R&D Stock	13,804	14,137	15,367	19,387	22,005	26,005	29,201	35,328	49,901	61,726
	Technology Imported	2,508	2,752	2,650	2,535	2,559	2,897	3,245	4,230	5,633	6,849
	Sum	16,312	16,889	18,017	21,922	24,564	28,902	32,446	39,558	55,534	68,575
Textile & Clothing(32)	R&D Stock	15,387	19,177	23,207	26,295	27,631	30,811	37,899	43,804	55,436	70,254
	Technology Imported	6,521	9,512	11,985	13,239	12,309	11,298	10,645	11,611	12,977	13,641
	Sum	21,908	27,689	35,192	39,534	39,940	42,109	48,544	55,415	68,413	83,895
Chemical, Petro Chem. & Plastic(35)	R&D Stock	35,683	36,588	48,536	57,246	66,231	71,958	83,474	110,839	157,998	204,558
	Technology Imported	29,554	46,126	60,517	68,748	86,834	88,923	90,162	39,625	96,551	103,401
	Sum	65,237	82,714	109,053	125,994	153,065	160,881	173,636	200,464	254,509	307,959
Non-Ferrous Mineral Product(36)	R&D Stock	15,798	16,396	18,469	20,190	18,368	18,740	19,841	21,936	26,804	32,841
	Technology Imported	3,207	3,332	4,118	4,732	6,306	6,968	7,582	9,006	10,374	11,257
	Sum	19,005	19,728	22,587	24,922	24,673	25,708	27,423	30,942	37,178	44,098
Primary Metal Product(37)	R&D Stock	27,294	27,648	31,132	35,401	38,870	36,966	39,975	42,762	47,443	56,766
	Technology Imported	25,060	27,207	30,880	27,651	28,650	27,343	25,820	25,921	26,457	27,989
	Sum	52,354	54,855	62,012	63,052	67,520	64,309	65,795	68,683	73,900	84,755
Machines & Equipment(38)	R&D Stock	83,556	91,343	114,973	141,839	158,517	186,135	223,696	275,434	385,869	588,187
	Technology Imported	26,534	37,725	43,572	59,171	74,938	100,260	122,764	149,451	207,197	270,515
	Sum	110,090	129,068	158,545	201,010	233,455	286,395	346,460	424,885	593,066	878,702
Other Manufacture(39)	R&D Stock	9,814	9.431	15,994	15,423	15,000	16,355	15,174	14,889	14,820	19,079
	Technology Imported	3,360	3,636	5,589	8,306	8,942	10,081	10,295	13,406	14,976	20,991
	Sum	13,174	13,067	21,583	23,729	23,942	26,436	25,469	28,295	29,796	40,070
Manufacturing (3)	R&D Stock	201,336	214,720	267,678	315,781	346,622	386,970	449,260	544,992	738,271	1,033,411
	Technology Imported	96,744	130,290	159,311	184,382	220,538	247,770	270,513	303,250	374,125	474,643
	Sum	298,080	345,010	426,989	500,160	567,160	634,740	719,773	848,242	1,112,396	1,508,054

Source : C.K. Kim and B.T. Cho, *R and D, Market Structure, and Productivity*, Seoul : Korea Development Institute, 1989, pp75-77

Table 12-b
Share of R&D Capital Stock by Manufacturing Sub-sectors 1977-1986

(Unit: Percent)

Industries ↓	Year →	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Food Processing(31)	R&D Stock	6.9	6.6	5.7	6.1	6.3	6.7	6.5	6.5	6.8	6.0
	Technology Imported	2.6	2.1	1.7	1.4	1.2	1.2	1.2	1.4	1.5	1.4
	Sum	5.5	4.9	4.2	4.4	4.3	4.6	4.5	4.7	5.0	4.5
Textile & Clothing(32)	R&D Stock	7.6	8.9	8.7	8.3	8.0	8.0	8.4	8.0	7.5	6.8
	Technology Imported	6.7	7.3	7.5	7.2	5.6	4.6	3.9	3.8	3.5	2.9
	Sum	7.3	8.3	8.2	7.9	7.0	6.6	6.7	6.5	6.2	5.6
Chemical, Petro Chem. & Plastic(35)	R&D Stock	17.7	17.0	18.1	18.1	19.1	18.6	18.6	20.3	21.4	19.8
	Technology Imported	30.5	35.4	38.0	37.3	39.4	35.9	33.3	29.6	25.8	21.8
	Sum	21.9	24.0	25.5	25.2	27.0	25.3	24.1	23.6	22.9	20.4
Non-Ferrous Mineral Product(36)	R&D Stock	7.8	7.6	6.9	6.4	5.3	4.8	4.4	4.0	3.6	3.2
	Technology Imported	3.3	2.6	2.6	2.6	2.9	2.8	2.8	3.0	2.8	2.4
	Sum	6.4	5.7	5.3	5.0	4.4	4.1	3.8	3.6	3.3	2.9
Primary Metal Product(37)	R&D Stock	13.6	12.8	11.6	11.2	11.2	9.6	8.9	7.8	6.4	5.5
	Technology Imported	25.9	20.9	19.4	15.0	13.0	11.0	9.5	8.5	7.1	5.9
	Sum	17.6	15.9	14.5	12.6	11.9	10.2	9.1	8.1	6.6	5.6
Machines & Equipment(38)	R&D Stock	41.5	42.5	43.0	44.9	45.7	48.1	49.8	50.5	52.3	56.9
	Technology Imported	27.4	29.0	27.4	32.1	34.0	40.5	45.4	49.3	55.4	61.2
	Sum	36.9	37.4	37.1	40.2	41.2	45.1	48.1	50.1	53.3	58.3
Other Manufacture(39)	R&D Stock	4.9	4.4	6.0	4.9	4.3	4.2	3.4	2.7	2.0	1.8
	Technology Imported	3.5	2.8	3.5	4.5	4.1	4.1	3.8	4.4	4.0	4.4
	Sum	4.4	3.8	5.1	4.7	4.2	4.2	3.5	3.3	2.7	2.7
Manufacturing (3)	R&D Stock	100.0	100.0	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0
	Technology Imported	100.0	100.0	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0
	Sum	100.0	100.0	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0

Source : C.K. Kim and B.T. Cho, *R and D, Market Structure, and Productivity,* Seoul : Korea Development Institute, 1989, pp75-77

Table 12-c

The Proportion of Domestic R&D and Imported Technology in Each Manufacturing Sub-sectors 1977-1986

(Unit : Percent)

Industries ↓	Year →	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Food Processing(31)	R&D Stock	84.6	83.7	85.3	88.4	89.6	90.0	90.0	89.3	89.9	90.0
	Technology Imported	15.4	16.3	14.7	11.6	10.4	10.0	10.0	10.7	10.1	10.0
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Textile & Clothing(32)	R&D Stock	70.2	66.8	65.9	66.5	69.2	73.2	78.1	79.0	81.0	83.7
	Technology Imported	29.8	33.2	34.1	33.5	30.8	26.8	21.9	21.0	19.0	16.3
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Chemical, Petro Chem. & Plastic(35)	R&D Stock	54.7	44.2	44.5	45.4	43.3	44.7	48.1	55.3	62.1	66.4
	Technology Imported	45.3	55.8	55.5	54.6	56.7	55.3	51.9	44.7	37.9	33.6
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Non-Ferrous Mineral Product(36)	R&D Stock	83.1	83.1	81.8	81.0	74.4	72.9	72.4	70.9	72.1	74.5
	Technology Imported	16.9	16.9	18.2	19.0	25.6	27.1	27.6	29.1	27.9	25.5
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Primary Metal Product(37)	R&D Stock	52.1	50.4	50.2	56.1	57.6	57.5	60.8	62.3	64.2	67.0
	Technology Imported	47.9	49.6	49.8	43.9	42.4	42.5	39.2	37.7	35.8	33.0
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Machines & Equipment(38)	R&D Stock	75.9	70.8	72.5	70.6	67.9	65.0	64.6	64.8	65.1	66.9
	Technology Imported	24.1	29.2	27.5	29.4	32.1	35.0	35.4	35.2	34.9	33.1
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Other Manufacture(39)	R&D Stock	74.5	72.2	74.1	65.0	62.7	61.9	59.6	52.6	49.7	47.6
	Technology Imported	25.5	27.8	25.9	35.0	37.3	39.7	40.4	47.4	50.3	52.4
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Manufacturing (3)	R&D Stock	67.5	62.2	62.7	63.1	61.1	61.0	62.4	64.2	66.4	68.5
	Technology Imported	32.5	37.8	37.3	36.9	38.9	39.0	37.6	35.8	33.6	31.5
	Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source : C.K. Kim and B.T. Cho, *R and D, Market Structure, and Productivity*, Seoul : Korea Development Institute, 1989, pp75-77

(1) During the 10 year period, the total R&D capital in the manufacturing sector grew over 5 fold (or approximately at an annual average growth rate of 17.5 percent).[20] The growth rate for machinery and equipment sectors (SIC 38) dominated with an 8 fold increase and also in terms of absolute volume. The chemicals and plastic sector followed in growth rate and absolute amount.

(2) Domestic R&D expenditures exceeded spending on technology imports by a factor of 2. This seems to suggest that although the core technology unavailable at home has been imported, efforts were made to minimize imported content of the total technology package. Domestic R&D efforts supplemented technology imports as much as possible. Several studies have drawn conclusions consistent with the above interpretation.[21] The proportion of domestic R&D shows even a greater dominance in the traditional sector such as the food processing sector, with 90 percent in 1986 and the textile and clothing sector with 83.7 percent. Presumably, the latter sectors seem to have achieved technological capabilities close to the best practice abroad.

The rapid speed of technological accumulation seems consistent with the dominant themes of industrialization policies during the past three decades. First, "the growth first" objective, coupled with the goal of achieving competitiveness in international markets, compelled private enterprises to learn to do new things, such as developing new markets, new products, new production processes, etc. The government encouraged them to import "state of the art" technologies rather than second-hand, labour-intensive, "appropriate" technologies, and also to reach the maximum engineering-determined output capacity at the shortest time of learning and mastering rather than maximizing shortrun profit. This strategy was applied to all investment projects launched under the Heavy and Chemical Industry Development Program during the 1970s. This strategy stems from the logic of "learning by doing, by imitating, by training" rather than from the logic of achieving the static, allocative equilibrium paradigm.

Second, besides the government encouragements provided by various forms of incentive schemes, the fierce competition among Chaebol groups, must be noted. This competitive nature created a rivalry for technological progress. Broadly speaking, Korean Chaebols imitated the behavior of Zaibatsu in Japan for product diversification, empire-building, and market-share competition through the practice of technology upgrading. It cannot be over-emphasized that competition has been a critical driving force for rapid growth, based on learning of new technology in Korea.[22]

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[20] During the same period the net physical capital stock has grown about 3 times. See H.K. Pyo, as shown in the source of Table 3, p.91

[21] See Enos, J.L. and W.H. Park, *The Adoption and Diffusion of Imported Technology : The Case of Korea*, New York : Croom Helm 1988 ; Westphal, L.E., Y.W. Rhee and G. Pursell, "Korean Industrial Competence : Where It Came From", World Bank Staff Working Paper No.469, July 1981. "That is what Korea did - fill the gaps for only a few industries at a time, persistently supplementing foreign resources by domestic resources. y following this course the Korean got alot of mileage from their investment in technology. Because they could unbundle the elements of imported technological packages, they did not waste money unnecessarily on the excessive baggage that often is a part of such packages." Rhee Y.W., B. Ross - Larson and G. Pursell, *Korea's Competitive Edge : Managing the entry into world markets*, The Johns Hopkins University Press, Baltimore, 1984. pp.46 and 49

[22] In contrast, the weakened force of competition under protection seems to have hindered technological learning in some developing countries, e.g. India and Brazil in the 1970s and 1980s. See Staffan Jacobsson and Ghayur Alam, *Liberalization and Industrial Development in the Third World : A Comparison of the Indian and South Korean Engineering Industries*, London : Sage Publication Ltd, 1994. This study concludes : "The Indian policy towards its industrial sector, on the other hand, was dominated by a whole set of restrictive instruments which greatly limited the

3.3 Sources of knowledge acquisition

As shown in Table 13, the evidence shows that a large portion of technologies have been imported from Japan and the United States in the form of capital goods with the sellers service of free instructions on how to use them.

Table 13
Total Number of Technology Imports by Source and Industry (1962-1992)

(Unit : Number of cases, %)

	EU	%	USA	%	JAPAN	%	Total
Food Processing	32	12.6	92	36.4	114	45.1	253
Textile	20	31.7	19	30.2	21	33.3	63
Chemical Fibre	182	47.0	71	18.3	131	33.9	387
China & Cement	43	19.2	41	18.3	132	58.9	224
Petro-Chemical	246	18.4	345	25.8	685	51.3	1,336
Pharmaceutical	52	26.7	70	35.9	57	29.2	195
Metal Products	75	17.9	81	19.3	240	57.3	419
Electric & Electronics	199	10.0	755	37.8	972	48.7	1,995
Machinery	352	16.8	363	17.3	1,279	60.9	2,099
Ship-building	123	54.7	28	12.4	50	22.2	225
Others	94	-	289	-	363	-	863
Total	1,418	17.6	2,154	26.7	4,044	50.2	8,059

Source : Korea Industrial Technology Association

Foreign direct investment has certainly contributed, but not dominantly, as in the case of Singapore or Hong Kong. The historical ties and economic distance (costs) would seem to explain the geo-political connection. Recall the Japanese (1910-1945) and the U.S. (1945-1948) occupations. It is worth pointing out that a large number of Korean students went to Japan and later the United States after the WWII. Their education in engineering, business administration as well as in other sciences has been crucial in determining and influencing the source of new knowledge, and the mode of assimilating them in the Korean economy. Today, a significant brain pool exists in the United States and Canada, with over 10,000 scientists and engineers, who have registered in the Korean-American Scientists and Engineers Association, Inc. The success and pace of the Samsung Group in developing DRAM chips for instance, owes to a great extent to engineers who returned from IBM, Bell Lab and AT&T, where they were engaged in R&D activities for years after graduation from American universities. This reverse of 'brain drain' should not be missed in explaining the Korean case.

room for manoeuvre of private industry. These included MRTP (Monopoly and Restrictive Trade Practices Act), industrial licensing policy and the policy vis-a-vis foreign technological collaboration. Indeed, the MRTP legislation aimed at restructing the growth of conglomerates with a superior risk-taking ability, precisely that form of business organization which has led development in Korea. Firm-specific and made-to-measure policies designed to help firms in their learning process seem to have been absent. ...." (p.233, ibid)

3.4 Accumulating human capital

Intuitively, it seems obvious that a higher complexity of technology would require a concomitant (higher) level of educated and trained manpower. One could readily hypothesize that a continuous supply of human capital is a necessary condition for upgrading industrial structure, through an adoption of more sophisticated technologies.[23] Indeed, Professor Fritz Machlup advances a "causal chain" of education, leading to improved performance and earnings, as follows :[24]

(1) educational investment improving mental ability
(2) educational investment improving the extra elements that make for capacity
(3) the actual utilization of that capacity resulting in work performance, and
(4) the number of hours of performance leading to earnings from work

Furthermore, Machlup distinguishes "eight components of the capacity to learn and perform tasks that demand cognitive aptitudes and moral attitudes of higher order : (1) mathematical ability, (2) verbal ability, (3) alertness (also enterprising spirit, moral courage), (4) creativity (resourcefulness, imaginativeness, inventiveness), (5) interest (intellectual curiosity, inquiring mind), (6) ambition (drive, resolution), (7) diligence (industry, working intensity), (8) perseverance (enduring dedication, constancy)."

One could question whether education and training could enhance these qualities or whether education really functions as a sifting device for talents.[25] One study on Korea concludes : "The evidence is not consistent with a conclusion that education generated growth, through some transformation of individuals from traditional to modern men or through the formation of human capital. ... Education in Korea does not appear to have expanded as a response to technological improvements in the economy requiring higher levels of ability among workers. Nor is there evidence that increase in the number of educated people anticipated (in some causal way) the economic boom of the 1960s".[26]

This analyzer obviously was looking for a "single variable causal relationship" in Korea. It seems

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[23] It seems self-evident that Korean transformation from an agricultural economy to an industrial economy depended upon an adequate supply of technical manpower, engineers and scientists which were virtually absent when the Japanese occupation ended in 1945. Then, even a rudimentary educational-and-training superstructure did not exist e.g. teachers, professors, textbooks, classrooms, etc. which can be taken for granted in developed countries. Thus the accumulation of human capital should become a center piece in explaining Korean experience. Such a work has not appeared yet.

[24] See his, *The Economics of Information and Human Capital*, Princeton University Press, 1984. p.469

[25] "It is true that the subject has failed to shed light on whether the productive role of education derives more from cognitive knowledge or behavioural characteristics, or even to make much progress with the fundamental issue of the distinction between the productivity and screening functions of schooling". K. Gannicott, "The Economics of Education in Asian-Pacific Developing Countries", *Asia-Pacific Economic Literature*, vol.4 No.1(March 1990), p.42. This debate is still going on ; see Orley Ashenfelter and Alan Krueger, "Estimates of the Economic Return to Schooling from a New Sample of Twins" *American Economic Review*, vol.84, No.5, December 1994. The authors concluded "that increased schooling increases average wage rates by about 12-16 percent per year completed. This is larger than most estimates in the prior literature."

[26] Noel F. McGinn, et.al. *Education and Development in Korea*, Harvard University Press (Cambridge, Mass.) 1980, p.240

to make more sense to regard educated and trained manpower as only one of several "inputs" enabling firms, industries and the economy (collectively) to learn new or imported technologies. In turn, mastering them leads to productivity growth and ultimately to international competitiveness. Explanation of this aspect of structural upgrading needs at least three factors and their interactions - namely, technological knowledge, human capital able to master the knowledge and institutional setup organizing them into a system of innovation. An abundance of human capital, if unorganized, could mean little. The cases of the Philippines and the C.I.S.(the former USSR) provide apt examples.[27]

With regard to the question of educational expansion in Korea, unrelated to "technological improvements in the economy requiring higher levels of ability among workers", a few explanations can be offered.

First, the Todaro model of rural-urban migration could be adapted to the case of education. His model is intended to explain why people move, even anticipating possible unemployment in the city. The basic idea is that the mover calculates "expected future income" after moving, multiplying the probability of getting employed by urban wages. If this sum exceeds by far the probable costs of moving, then it is rational for the person to move.[28] Similar reasoning applies to education. One would decide to get education and training even if the person anticipates possible unemployment after graduation, if the "expected future income" reflecting education achieved exceeds the probable costs of education.

Second, education could be regarded, as not only just an asset creating income, but as an asset generating respect, social prestige, and ability to appreciate a future stream of intellectual consumption such as appreciating art, music, literature, history, philosophy and other knowledge, even on science and technology. Moreover, the Confucian tradition values learning ; and the desire for learning among Korean people was suppressed during the Japanese occupation period. The "pent-up demand for education" was released at least partly in the post WWII period.

Third, beside the investment-plus-consumption values of education, the zealous demand for education would seem to reflect the consensus that "national independence (liberation from the Japanese domination) and survival depends on uplifting the level of enlightenment of Koreans through education." This thought permeates virtually all writings and speeches concerned with education and the national future. It is difficult to demonstrate the quantitative strength of the enlightenment campaign on the psyche of the Koreans and the revealed demand for education. But, neglecting this factor seems unjustified, despite the measurement problem.

The exceptional zeal for education served the goal of industrialization well, particularly if education externalities are real and strong. Theodore Schultz advances the idea that human capital has external effects. "These effects spill over from one person to another. People at each skill level

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[27] The Philippines has invested in education such a way as to produce proportionately more college graduates than in Korea throughout the 1970s and 1980s. See Tan, Jee-Peng and Alian Mingat, *Education in Asia : A Comparative Study of Cost and Financing*, The World Bank, Washington,D.C. 1992 ; Hiromitsu Muta(ed.) *Educated Unemployment in Asia*, Tokyo : Asian Productivity Organization, 1990

[28] Michael P. Todaro, "Income Expectations, Rural-Urban Migration and Employment in Africa" *International Labour Review* November 1971, pp391-413

are more productive in high than in low human capital environment. Human capital enhances the productivity of both labour and physical capital...." Rapid urbanization and the geographical concentration of the highly educated in Korea seem to support the view. It remains high in the research agenda to test the education externality hypothesis with the Korean experience. However, the evidence in existence, though scant, suggests rather significant externalities.

Table 14 shows an increasing trend in the social rate of return on educational investment estimated for the 1967-85 period. This seems consistent with the hypothesis put forward by Professor Schultz. In other words, college education seems to become more productive as the human capital stock, particularly the college graduates, increase in number over the years. One can conjecture, that as digital technology spreads in all industries, the productivity of college graduates would increase even further.

Table 14
Trend of Social Rate of Return (on education)

Year	Middle School	High School	College & Univ.
1967	12.0	9.0	5.0
1968	20.0	11.0	9.5
1969	-1.0	15.0	8.5
1970	8.2	14.6	9.3
1971	2.9	5.7	1.9
1972	3.7	2.9	1.3
1977	2.8	9.9	13.8
1980	2.9	8.1	11.7
1982	9.5	12.3	13.0
1985	11.2	7.6	14.5

Source : Korea Educational Development Institute, Educational Investment and Rate of Return to Education, Seoul 1985

To sum up this section, it is hypothesized, that uplifting the industrial base technologically, requires an increasing amount of human capital. Furthermore, the educated and trained manpower must be organized with an "optimal" structure of incentives, information flows, and risk-sharing arrangements, given the goal of rapid learning. This is the subject of the next section on institution-building.

3.5 Crafting institutional devices for learning

The importance of institutions has been gaining recognition in recent years as the burgeoning literature attests.[29] Particularly, the comparative studies on enterprise-level organization between the

[29] See Thrainn Eggertsson, *Economic Behavior and Institutions*, Cambridge University Press, 1990 ; Geoffrey M. Hodgson, *Economics and Institutions - A Manifesto for a Modern Institutional Economics*, Polity Press, 1988; Douglas C. North, *Institutions Institutional Change and Economic Performance*, Cambridge University Press 1990 Mancur Olsen, *The Rise and Decline of Nations, Economic Growth, Stagflation, and Social Rigidities*, New Haven, Yale University Press, 1982

U.S., Japan, and European countries have brought out significant differences in institutional instruments in use. In turn, these differences are regarded as determining the risk-taking behaviour, as well as the learning behaviour of individual firms.[30] Thus for example, the Japanese practices of horizontal flow of information, job rotation, autonomy at the shop floor, company loyalty, life-long employment, consensus-oriented industrial relation and decision making, etc. have been asserted to contribute to enhancing process innovation and continuous improvement for productivity.

The recent developments in the C.I.S. (Confederation of Independent States) would seem to provide even more dramatic evidence regarding the importance of basic institutions for industrial growth. The absence of basic rules of the game governing factories, the banking system and the property rights for instance has been attributed to the wreaking havoc that they have been experiencing in recent years. Institution-building has been recognized as the most urgent imperative, that will take years of work and "investment".[31]

A similar view could be expressed with respect to the institutional difference between North Korea and South Korea leading to the growing gaps in productivity and technological capability during the last 3 decades.

It is hypothesized in this section that the institutional matrix in an economy defines :

(1) information flow structure
(2) incentive structure
(3) uncertainty levels that firms face
(4) transaction costs
(5) effective rules for competition and cooperation

Moreover, some arrangements of institutional devices would turn out to be more efficient than others, as observed between different economics, as well as between different firms. While the general risk-taking activities, investment decisions are affected by these five factors, technological risk-taking activities such as R&D effort or quality controls, and learning seem even more crucially governed by them especially since the markets for technologies and human capital are imperfect or even non-existent in developing countries. This implies that some institutional devices must be crafted to overcome or manage such market failures. The Korean experience would seem to provide a fertile ground to explore her own way of managing externalities, complimentarities, lumpiness, cumulativeness, tacitness, path-dependence, uncertainties and asymmetric information which distinguish technology and its capability from other goods and services.

Some examples of Korea-invented institutions have been mentioned earlier such as KAIST, KIST, KIET, KPC and so on. There are many other institutions worthy of careful analysis such as the Economic Planning Board(EPB), Korea Foreign Traders Associations(KFTA), Korean Federation

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[30] For example, see Ronald Dore, *British Factory-Japanese Factory* (The Origins of National Diversity in Industrial Relations), Berkeley and Los Angeles : University of California Press, 1973 ; Masahiko Aoki, *Information, Incentives and Bargaining in the Japanese Economy*, New York : Cambridge University Press, 1988 ; and The MIT Commission on Industrial Productivity, *Made in America, Regaining the Productive Edge,* Cambridge, MIT, 1989

[31] Rey Koslowski, "Market Institutions, East European Reform, and Economic Theory," *Journal of Economic Issues,* Vol.26, No.3 (September 1992), pp.673-704

of Industries(KFI), Association of Small and Medium Industries and a myriad of producer's associations etc, all collectively forming a network of information generation and dissemination (repairing the market imperfections in effect). Below, two Korean inventions or institutions are selected and sketched as they have played a major role in advancing technological learning. They include (1) Chaebols (or conglomerates), (2) Trade regime as a learning device.

3.6 Chaebols as learning institutions

Chaebol groups or industrial conglomerates, as in the case of the Japanese Zaibatsu groups, have been the leading actors in the process of transforming an agrarian Korea to a capital-cum-technology intensive industrial economy.[32] The dynamism of this institutional form is manifested in various performance indicators such as rapid growth of sales, exports, employment figures, asset values and consequently business concentration indexes. However, Chaebols have often been the target of criticism regarding their "greeds, exploitation of consumers, government-business symbiosis at the expense of the public, as well as the poor and the small scale industries, unfair practices of 'octopus-like preying' of the weak enterprises, etc." Regardless of the variety of the criticism, their contributions to technological learning and building capability to achieve rapid industrial upgrading in the economy seems unmistakable.

The records of application for intellectual properties, the number of cases applied for patent, utility, design and trade mark are shown in table 15. These figures represent the first 29 companies ranked by the size of the total applications. It is to be noted that almost all the companies listed belong to the front-running Chaebol groups, namely, Samsung, Lucky-Gold Star, Daewoo, Hyundai and Kia. Furthermore, applications are concentrated in the fields of electronics, telecommunication, automobiles and machinery. These fields represent battle grounds with fierce competition for learning new technology in the 1980s, 1990s and beyond.

The reasons accounting for the leadership of Chaebols in technological-risk-taking activities are several. From the beginning of the early 1960s, when the transformation toward industrialization began, Chaebols have been following a diversification strategy, as a means to quickly build an empire. This strategy required Chaebols to employ college graduates from top universities every year, train them to indoctrinate and enhance their company-specific skills and technologies. See Table 16 for expenditures by leading Chaebols for training. Competition for hiring well-educated college graduates has been a force to raise their salaries well above the national average. Chaebols had a deep pocket affording such a choice. Furthermore, under the Chaebol group organization, a

[32] Korean Chaebols seem to have adopted the Japanese institutional form but with significant changes. "Despite some differences in management styles such as Japanese groupism and bottom-up decision-making versus Korean individualistic dynamism and top-down decision-making, Koreans have successfully adapted the Japanese systems in their own way. The top-down decision-making system was probably necessary for Korea to catch up with advanced technologies in a short period of time in a less expensive manner" Hiroshi Kakazu, "Industrial Technology Capabilities and Policies in Selected Asian Developing Countries" Asian Development Bank Economic Staff Paper No.46, Manila, June 1990. pp.21-22. See also Chan-Sup Chang, "Comparative Analysis of Management System : Korea, Japan and the United States". *Korea Management Review*, 13 (1), 1983, pp 77-98

failure of a new project in a member company could be covered by successes of projects in other member companies - a form of risk-sharing device.

Table 15
Number of Applications for Intellectual Property Right
by 29 Leading Companies in 1992

Company	Patent	Utility	Design	Trademark	Total
Samsung Electronics	3,410	1,933	355	299	5,997
GoldStar	2,318	3,234	174	159	5,885
Daewoo Electonics	435	1,397	384	33	2,249
Hyundai Automobile	348	1,062	606	17	2,033
Hyundai Electronic Indust.	930	490	367	13	1,800
Samsung Electricity	198	551	24	2	775
GoldStar Communication	344	324	30	5	703
GoldStar Electron	318	351	2	-	671
Samsung Display Devices	300	266	11	1	578
Orion Electricity	73	452	50	-	575
Kia Automobile	74	306	174	2	556
GoldStar Telecom	235	207	21	-	463
POSCO	197	253	3	-	453
GoldStar Industrial System	76	321	8	4	409
Korea Electronics &	349	1	-	1	351
Daewoo Motor Co.	34	193	85	5	317
Mando Machinery	52	182	49	1	284
GoldStar Cable	127	121	20	9	277
Daewoo Telecom	67	145	48	16	276
Samsung Aerospace	87	149	8	2	246
Samsung Heavy Industry	59	147	4	30	240
Asia Automobile	27	94	99	9	229
Daewoo Electronic Component	52	160	13	-	225
GoldStar Electric Machinery	50	151	3	5	209
GoldStar Alps Electronics	39	101	1	-	141
GoldStar Instru. & Electric.	36	92	1	-	129
Daewoo Heavy Industry	11	67	1	2	81
Samsung Corning	38	34	-	-	72
Daewoo Ship Industry	15	35	1	18	69
Daewoo Subsidiaries(7) Total	687	2,449	582	74	3,792
Samsung Subsidiaries(6) Total	4,092	3,080	402	334	7,908
GoldStar Subsidiaries(9)Total	3,543	4,902	260	182	8,887
Hyundai Subsidiaries(2) Total	1,278	1,552	973	30	3,833

Source : Republic of Korea Government Patent Office

Table 16
Investment Expenditures for Education and Training of Employees
by Major Chaebol Groups (1992 and 1993)

(Unit : Million Won)

	1992	1993
Samsung	31,348	40,837
Hyundai	11,498	13,935
Daewoo	15,530	19,218
Lucky Gold Star	18,333	23,319
Hanjin	9,290	10,016
Kia	6,761	8,211
Sunkyung	6,637	7,223
Ssangyong	5,991	7,334
Daelim	1,732	2,019
Byuksan	1,977	2,147
Hanil	230	190
Hanhwa	2,482	3,185
Kumho	3,328	3,711
Dusan	3,058	3,302
Dongkuk Steel	577	575
Hyosung	1,277	1,460
Lotte	4,097	4,208
Sammi	168	110
Kohap	201	158
Kolon	3,095	3,649
Dongyang	2,482	3,617
Halla	1,449	2,583
Haitai	2,293	2,254
Dongah	1,939	2,639
Woosung Const.	604	1,130
Dongbu	1,167	1,872
Kumkang Shoes	710	477
Kukdong Const.	1,878	1,573
Hanbo	270	176
Miwon	1,507	1,877

Source : HanKook KyungJe Shinmun (Korea Economic Daily)
July 6, 1994

Gong Byong Ho, having studied the history of Chaebols, concluded : the high growth strategy through diversification brings what he calls "economy of growth".[33] First, high growth tends to increase the efficiency of the line workers because of accumulation of production-related experiences (or learning by doing, imitating, and using). It also tends to create greater opportunities for promotion, an added incentive, to lower the average age of employees as well as to disperse or reduce risks and uncertainties. Thus, bankers are more willing to lend money to Chaebols, which diversify and grow faster than otherwise. Diversification normally meant learning new technologies for product and process development.

Gong concludes also, that the Chaebols, with an aggressive diversification strategy into new products and markets, had maintained a greater survival potential through rapid learning-productivity linkages. One must add also, that those with a greater export-performance record, had benefited more from the government incentive schemes, such as tax breaks, subsidized-interest loans,

[33] This concept differs from "economies of scale or advantages of mass production". See his *Rise and Fall of Korean Enterprise,* Myong-Jin Publishing co., Seoul, 1995 pp.147-154 (in Korean)

foreign-exchange access, etc.[34] Thus the Chaebols, which could diversify into foreign markets and into new products for export, could redouble their advantages.

High rates of technological learning and diffusion among Chaebols have been supported by high growth policy. Yang Taek Lim has estimated the rate of new technology diffusion for Numerical Control (NC) Equipment, and compared the diffusion speed between Canadian and Korean industries. In the case of General Machine sector, the Korean large scale enterprises have achieved a speed index 0.3929, a 3 fold rate of Canadian counterpart at 0.1303. The Korean small and medium enterprises have achieved a rate of 0.2070 or 1.6 times of the Canadian counterpart. Similar results have been recorded in other sectors including Electronic Equipments and Transportation Equipments.[35]

It should also be emphasized, that as the Chaebols increased their wealth, they were able to take greater risks in technology-intensive projects, with a higher stake. For example, Samsung had invested aggressively in developing capabilities for semi-conductor production early in 1980s. When foreign sources refused Samsung's access to crucial technologies, Samsung decided to establish its own R&D firm in the Silicon Valley hiring Korean-American engineers and scientists along with foreigners. The R&D firm provided a convenient outpost for supplying state-of-the-art knowledge and for manpower training.[36]

Samsung's investment in semi-conductors has begun to yield dividends only in 1993, but it turned out to be a "cashcow" of the group in 1994 and 1995. The hard-won financial gains seem to be providing a new wherewithal for a new technological leap forward in related areas, such as ASIC designs, HDTV areas, electronic packaging, and static ROM, etc. Such linkage effects, one leading to another, seem to reinforce and to complement the cumulative effects of learning-by-doing.

To conclude this section, it can be advanced that a Chaebol, a form of institutional device, has served well as the main actor in technological-capability building. It has helped to reduce risks and uncertainties of new projects, to diversify product portfolio and overseas markets, to exploit dynamic scale economies, externalities, and the benefits of cumulative knowledge stock, and so on. But it should be stressed that Taiwan had not relied on anything like conglomerates. For historical reasons the Chang Kai Shek government shunned conglomeration and nurtured medium and small scale enterprises. The Chaebol, as a form of an institution, was neither a necessary nor a sufficient condition, but only a convenient "institutional tool" adopted to organize and manage the market imperfections and failure phenomena in Korea.

And finally, it must be pointed out that Chaebols have been used as an instrumental tool to compensate for the absence of a venture-capital market in the beginning of the industrialization in

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[34] Furthermore, some Chaebols have been allowed to establish a general trading company in order to exploit its capability to gather marketing information in the global market - another institutional device learned from Japan - See Cho, Dong-Sung, *The General Trading Company, Concept and Strategy*, Lexington Books D.C. Heath and Company, Lexington, Mass. 1987

[35] See his "A Study of Technology Diffusion at Enterprise Level with Special Reference to Machinery Sectors" Seoul ; Korea Economic Research Institute, April 1988(in Korean).

[36] See Young-Rak Choi, "Dynamic Techno-Management Capability (The case of Samsung Semiconductor Sector in Korea)", Ph.D. Thesis, Department of Economics and Planning, Roskilde University, Denmark, August, 1994, pp 112-114

Korea. In industrialized countries, venture capital helps entrepreneurs to initiate a risky project with a high stake by spreading uncertainties over the whole set of venture businesses. The fundamental uncertainties in developing countries precludes such a venture capital.[37] Under the circumstance, the government provided "subsidized loans" (e.g. the "policy loans") to Chaebols with the de facto effect of a risk-sharing partnership. If the project was successful the profit so earned would belong to the Chaebols, and if the project failed, the government and ultimately the tax payer would bear the cost. [38] Having fattened the Chaebols for some time, the government encouraged the family-owned stocks to be listed in the slowly burgeoning equity market. In the absence of an efficient capital market in Korea, this method of "enticing capital formation and its market" may be considered far better than nothing. The fundamental reason for the absence of capital market can be attributed to the "fundamental uncertainty", poverty, and the lack of technical knowledge, as well as experience. The policy loans have functioned as "surrogate venture capital." This makeshift arrangement provided an opportunity for private enterprises to engage in "learning by doing or imitating".

3.7 Trade regime as a technology learning device

How an export-oriented, outward-looking, industrial strategy is linked with the process of industrial deepening, deserves a high priority for research.[39] Recently an interesting hypotheses has been advanced stating that NICS in Asia have benefited from foreign buyers, transnational corporations (TNCS), original equipment manufacturer (OEM) arrangements, and licensing deals. These arrangements have provided avenues through which technical specification, training, advice on production and management, even with marketing information, have been made available. Mike Hobday called this an "export-led or export-pull technology development."[40]

Undoubtedly, such a export-pull technological development must have played a part in building technological capabilities in South Korea. However, it is also important to notice that the benefit of foreign buyers, OEM arrangements and TNC operations often provide limited opportunities for value adding only in the initial stages of acquiring market niche. The more difficult part of technology learning comes when OEM buyers and TNCs refuse to provide the more sophisticated parts of a technology, on the ground of potential competition. This is often called a "boomerang effect". Thus as an institutional arrangement, the so-called export-pull phenomena in technology learning, would

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[37] The same reason explains the absence of all forms of insurance companies - life, disaster, damage, even automobile insurances, during the 1950s and 1960s.

[38] See Cho, Y. J., for such an interpretation, "Finance and Development : the Korean Approach" *Oxford Review of Economic Policy*, vol.5, No.4, Winter 1989

[39] Robert E. Lucas has attempted to build a model to explain the growth performance of Korea as compared with the Philippines by linking the effect of learning spillover with trade and product diversification. See his "Making a Miracle," *Econometrica*, Vol.61, No.2 (March 1993) pp.251-272. But the model fails to consider the organizational variable which seems crucial to explain the difference in performance.

[40] See his "Export-led Technology Development in the Four Dragons : The Case of Electronics" *Journal of Development Studies*, October 1994, pp. 333-361. Similar view has also been expressed by Larry Westphal. See Westphal, L.E., Y.W.Rhee and G. Pursell, "Korean Industrial Competence : Where It Came From," World Bank Staff Working Paper, No.469, July 1981, p.72

easily stop short in the process of industrial deepening at the lower end of the technology ladder. An ongoing process cannot rely solely on this, though the OEM's positive contribution should be given due credit.

South Korea seems to have developed a set of trade-related institutional devices to overcome barriers in accumulating technological capabilities. Below is an attempt to briefly describe the features of such devices, which define also the trade-regime components.

The very first feature of the trade regime is the well-crafted combination of export promotion schemes and the program of selective import substitution. Commonly it is thought that these two approaches would be contradictory. Import substitution policy would tend to hinder exports because the domestic price rises to the extent that the market is protected. Across-the-boards tariff protection, as practiced in India and Latin American countries, for example, provide an example of such a situation. However, the South Korean trade regime would appear to have been finely "calibrated" and managed to remove anti-trade effects.

Though protective walls have existed, export producers were allowed to import the necessary inputs at the world market price and sell the output abroad at the world market price. Thus Korean exporters were exempt from the usual disadvantages of protective walls. The phenomenal export growth during the 1960s and 1970s, at an annual average growth rate of around 30 to 35 percent owes partly to the "free-trade" conditions, facing exporters, as in Hong Kong.

Meanwhile, the protected domestic market provided a "learning ground" for those product items selected for nurturing. The case of the automobile industry would help illustrate the learning process in that industry. An automobile consists of 20,000 parts. When the first assembly line was established in South Korea in the early to mid 1960s, most of the parts were imported. The domestic content was about 20-25 per cent. But slowly, increasing numbers of parts have been "locally" produced. The selection criteria for additional parts to be localized include : (1) those parts with less demanding complexity of technology and engineering resources ; (2) those parts with large balance of payments effects ; (3) those parts with smaller requirements for capital funds and skilled labour ; (4) those parts which can be developed in a shorter period of time ; (5) those parts, imports of which from Japan exceed 40 percent of the total Korean consumption ; (6) those with large spillover or linkage effects. By 1985 when the finished product of automobiles began to be exported, the domestic content rose to over 90-95 percent.

To decide on the annual target package of parts, the "Industrial Policy Deliberation Council" meets two or three times a year.[41] The Council consists of representatives from industry, banks, academia, trade associations, engineers and government officers. They deliberate collectively and agree on the annual package. The result of the collective agreement is made public immediately. This information has great value to individual producers, since the information signals access to bank

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[41]This council can be regarded as an arm of the National Conference for Technology Promotion presided over by the President himself. The Council helps to define details and implement them following the general tenet of subjects agreed upon at the Conference. For instance, during the 1986-87 period, the localization program has succeeded in achieving $1,360 million worth of import replacement plus $700 million worth of export creation owing to 727 of product items which have been localized. See Korea Industrial Technology Association, *Industrial Technology White Paper*, 1988, p.301

credits and uncertainty reduction measures (e.g. free information on technology sourcing, tax benefits, etc.).

Based on this information, which defines the next batch of goods to be technologically conquered, producers can begin competition for getting "subsidized credits" for investment in R&D as well as production facilities. Potential producers apply to the subcommittee of the Council for being selected and designated as a receiver of an assistance package. Selection criteria includes the producers' potential to become competitive sooner than others, past performance as exhibited by export records, soundness of engineering and management standards, etc. This process is akin to selecting and nurturing a champion in athletic activities. Those selected become eligible to receive assorted assistance for various services as listed in Table 17.

Table 17
List of support schemes to replace imports with local production and to upgrade the industrial base in the Republic of Korea

A. Financial support schemes	Manufacturing development fund Industrial technology improvement fund New enterprise creation support fund Technology development fund Venture capital fund Special fund for small and medium enterprise Equipment fund for export and import substitution in raw materials component parts Lease fund Procurement fund for domestically produced machines
B. Tax benefit schemes	Income tax exemption for foreign engineers Exemption of local tax for real estate to construct research institutes by enterprises Tax exemption for income from technology sales Income tax exemption for technology-intensive enterprise initiators Special accelerated depreciation allowance for projects using new technology Tax credit plus accelerated depreciation for research and development equipment and vocational training equipment Reserve funds for research and development accounted as losses Tax credit for expenditures on research and development and training Tariff reduction (65 to 70 per cent) on imports of high-technology industrial equipment
C. Technology support schemes	Special research and development projects Basic technology research and development projects Technical guidance on Long-term training of researchers Implant technical personnel development Simplified automation project Invited foreign experts Free technological information dissemination Free use of expensive test equipment Test of precision equipment and repairs Quality seal for domestically produced machines, parts and raw materials Support measures for obtaining foreign quality seals
D. Miscellaneous support schemes	Comprehensive support package for promising small- and medium-scale suppliers of new products System of identifying promising list of new exportable products(free marketing research) and priority products for import substitution Exhibition of domestically produced machines Government preference to procure domestically developed new products Anti-dumping tariff system Protection scheme for newly developed products with domestically developed technology Monitoring system to observe impacts of new products Fair trade and transaction law Exemption of military services requirements for core researchers Free consulting service for promotion of localization programme

Source : K. R. Lee, et.al. *Interim Evaluation of Localization Policy and Ways to Improve*, Korea Institute for Economic and Technology, Research Report No.196, April 1990, p.28

How these items of assistance are selected and combined can only be explained by presenting detailed rules of application. Such a task is beyond the scope of this paper. It suffices to point out that rules do exist. But they are also subject to negotiation and judgement (much as a medical doctor could prescribe drugs for a patient). It seems therefore, that there may have been plenty of rooms for rent-seeking opportunities. It seems also true however that upgrading of technological capabilities have been assisted and accomplished. The existing studies tend to evaluate the overall effect of the incentive structure positively rather than negatively.[42] These localization programs are constantly reviewed and evaluated, such as measuring the extent of localization and foreign exchange saved. If those firms receiving government assistance were to turn out failing in producing the expected results, they would be eliminated from the next round of competition for assistance. Such is the rule of the game, accepted by both the bureaucrats and the producers or the aid recipients.

Competitive pressure has also come from the longrun program of lowering protection through temporary exceptions on the "selected product" designated for technological upgrading.

The import liberalization program was nominally begun in 1967 when South Korea joined the GATT and shifted from a "positive list system" to a "negative list system." However, the really serious efforts were put into effect from 1978 when the Committee on Import Liberalization Measures was created and presided over by the Minister of Commerce and Industry. The Committee would meet periodically to decide on the list of products which would be allowed for import without quantitative restrictions. The list would be published with sufficient lead time so that the import-competing industries could be prepared. The committee declared that this policy would be so devised, that it will be useful for the purpose of upgrading industrial structure and competitiveness. Table 18 lists indicators of import liberalization since 1965.

[42] See for example, K. R. Lee, et. al. *Interim Evaluation of Localization Policy and Ways to Improve*, KIET, April 1990.

Table 18
Estimate of overall degree of import liberalization for Korea., 1965-90(%)

	Average rate of legal tariffs Regular[a] (1)	Total[b] (2)	Inverted total tariff rate [1/1+(2)] (3)	Degree of liberalization from QRS[c] (4)	Overall degree of liberalization (5)
1965	49.5	52.7	65.5	6.0	35.8
1966	49.5	52.3	65.7	9.3	37.5
1967	49.5	52.6	65.5	52.4	59.0
1968	56.7	58.9	62.9	50.1	56.5
1969	56.7	58.3	63.2	47.1	55.2
1970	56.7	58.5	63.1	46.3	54.7
1971	56.7	57.9	63.3	47.0	55.2
1972	56.7	57.5	63.5	43.4	53.5
1973	48.1	48.2	67.5	44.7	56.1
1974	48.1	48.1	67.5	43.8	55.7
1975	48.1	48.1	67.5	41.6	54.7
1976	48.1	48.1	67.5	44.1	55.8
1977	41.3	41.3	70.8	40.8	55.8
1978	41.3	41.3	70.7	52.2	61.5
1979	34.4	34.4	74.4	56.2	65.3
1980	34.4	34.4	74.4	57.4	65.9
1981	34.4	34.4	74.4	60.7	67.6
1982	34.4	34.4	74.4	62.5	68.5
1983	34.4	34.4	74.4	66.6	70.5
1984	26.7	26.7	78.9	75.0	77.0
1985	26.4	26.4	79.1	78.2	78.7
1986	24.7	24.7	80.2	82.0	81.1
1987	23.9	23.9	80.7	84.1	82.4
1988	22.4	22.4	81.7	86.0	83.9
1989	15.7	15.7	86.4	86.7	86.6
1990	14.1	14.1	87.6	87.5	87.6

Source : Kwang Suk Kim, "Trade and Industrialization Policies in Korea" in G. K. Helleiner, Trade Policy and Industrialization in Turbulent Times, London, Routledge 1994

[a] The average rate of regular tariffs, weighted by the value of 1975 production.

[b] Includes the average rate of special tariffs on imports in addition to the regular tariffs for the 1965-73 period.

[c] Represents the degree of import liberalization from QRs(quantitative restrictions) based on both trade programme and special laws.

An evaluation of this import liberalization program, conducted by KDI, suggests that indeed the program had an effect of bracing the domestic producers for upgrading competitiveness through innovation.[43]

It would seem that the slow and measured import liberalization has functioned as a significant (threat) component of the whole incentive structure for enticing innovation and learning.

Another important feature of the incentive structure is the emphasis on importing state-of-the-art technology and mastering it as fast as possible. From experience, the policymakers saw "second-hand" technology become obsolete too fast. Also product quality can be achieved and maintained in a competitive overseas market with only the most advanced machines. Nurturing ability to produce

[43] Soogil Young, "Import Liberalization and Industrial Adjustment", KDI Working Paper 8613, Seoul : Korea Development Institute, December 1986

high quality products to be sold in export markets is the guiding principle for choosing "appropriate technology", not the existence of cheap unskilled labour in abundance, dictating labour-using technology.

Once a machine, plant or technology licence was purchased, the next step was to reach the maximum output capacity level, defined by engineers, as soon as possible. This step seems consistent with the learning by doing (imitating) hypothesis and not necessarily with a shortrun profit-maximization assumption.

There has been the general agreement among bureaucrats and producers, that the "success" of technology mastering has to be measured by the import needs (e.g. parts or feedstock) replaced by localization, or even better, the amount of exports newly created. It makes sense that world-market acceptance provides the most stringent test of quality and price, and therefore, renders a clear yet simple standard of success or failure of technology mastering.

To recapitulate the trade regime functioning as an institutional device for building technological capabilities, the following features should be noted : (1) Export promotion policies helped to reduce or eliminate anti-export biases of selective import sustitution measures ; (2) Surging export earnings allowed producers to be able to import either new technologies under licensing arrangements or capital goods embodying state-of-the-art technologies, with the aim of gaining competitiveness and productivity in world markets ; (3) The trade regime offered two avenues of technological learning ; the first avenue was the request for quality upgrades by foreign buyers and OEM patrons, who often provided free consulting services ; and the second avenue was the "localization program" whereby domestic content of exportables has been augmented via backward linkage serving export activities (i.e. parts, feedstock, intermediate infants etc.). There is some evidence indicating that non-export sector growth has greater correlation with productivity growth than export sector growth. See Table 19.

Although further confirmation may be needed, one could interpret the evidence as showing greater learning effects, and hence productivity growth, in import-competing industries, and/or export-supporting linkage industries, compared with the export industries per se.[44]

Under a trade-regime designed to encourage the upgrading of technological capabilities of enterprises, an able producer can expect a package of assistance tailored for his needs. He can have "free" information on where he can sell his new products, on what sort of technologies are available at what price, on what terms be can borrow money (usually at subsidized interest rates), what sort of tax benefits he can claim, etc. The access to such information alone can help to reduce transaction costs, as well as uncertainties facing the exporter, as compared with the absence of such a service system under the laissez faire condition.

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[44] "... The speed of technological progress in overall industrial performance in Korea has been measured to be twice as fast as in Japan ; 2.6 times as fast in the case of manufacturing ; and 5 times as fast in Heavy and Chemical Industries.... Where import replacement by local production has been flourishing". Min, Kyung Whee, *The Changes of Input-Output Structure in Korean Industries : A Comparison with Japan*, Korea Institute for Industrial Economics and Technology, Research Series 93-08, 1993, p.154, (in Korean).

Table 19
Regression coefficients explaining growth rate of total factor productivity by manufacturing subsectors with export and non-export production[a)]

		C	A	B	
3	Manufactures	--7.751 (-1.943)	0.763 (3.603)***	-0.001 (-0.007)	[R^2=.54]
311/2	Food	-3.573 (-0.590)	0.653 (2.617)**	-0.087 (-1.279)	[R^2=.34]
313	Beverages	-9.344 (-2.646)*	1.317 (7.087)***	0.075 (2.074)*	[R^2=.76]
314	Tobacco	-4.795 (-1.239)	1.026 (7.642)***	-0.003 (-0.407)	[R^2=.79]
321	Textile	1.446 (0.272)	0.869 (3.313)***	-0.294 (-1.688)	[R^2=.41]
323	Leather	-2.430 (-0.285)	0.120 (5.121)***	-0.021 (-0.163)	[R^2=.65]
331	Wood and cork	2.438 (0.408)	0.284 (1.564)	-0.262 (-1.684)	[R^2=.32]
332	Furniture	-7.384 (-1.302)	0.439 (5.339)***	0.116 (2.701)**	[R^2=.65]
341	Paper products	-11.405 (-2.531)*	1.037 (5.101)***	0.008 (0.957)	[R^2=.63]
342	Printing	-9.119 (-2.544)*	1.138 (8.162)***	-0.003 (0.189)	[R^2=.84]
351/2	Industrial and other chemicals	-13.506 (-2.458)*	0.968 (6.713)***	0.096 (1.688)	[R^2=.74]
353/4	Petroleum refining	-5.834 (-1.053)	0.197 (1.346)	0.013 (1.511)	[R^2=.24]
355	Rubber products	-1.173 (-0.272)	0.520 (3.616)***	-0.035 (-0.455)	[R^2=.53]
361/2/9	Pottery, china	-8.382 (-1.931)	0.685 (3,437)***	-0.003 (-0.129)	[R^2=.43]
371/2	IroN and steel and non-ferrous metals	-9.016 (-1.235)	0,584 (2,703)**	-0.011 (-0.178)	[R^2=.32]
381	Metal products	-5.579 (-1.396)	0,312 (5,403)***	0.115 (-2.411)*	[R^2=.66]
382	Machinery	-8.753 (-2.177)*	0,520 (6,271)***	-0.080 (-1.303)	[R^2=.74]
383	Electrical machinery	-13.781 (-1.925)	0,335 (2,206)*	0.253 (2.601)*	[R^2=.55]
384	Transport equipment	-0.760 (-0.122)	0.516 (2.931)***	0.022 (0.470)	[R^2=.43]
390	Other manufactures	-2.746 (-0.357)	0.522 (2.267)*	-0.001 (-0.002)	[R^2=.29]

[a)] Regression equation:

$$\left(\frac{dT}{T}\right) = C + A\left(\frac{dD}{D}\right) + B\left(\frac{dX}{X}\right)$$

where (dT/T) : Growth rates of TFP (Solow index)
C : Constant
(dD/D) : Growth rates of non-export production
(dX/X) : Growth rates of export production

Note: Figures in brackets are t-values.
Data: Time series 1966-1985 in 1980 prices.

* Significant at 5 per cent
** Significant at 2 per cent
*** Significant at 1 percent

Source : Youngil Lim, "Industrial Policy and Productivity Gains : South Korean Evidence", *Journal of Economic Development,* Vol.18, No.1 (June 1993), p.76

But the assistance package is available not to everyone who wants it, but only to those who pass the screening. The ability indicators for screening purposes include past performance of exports or record of successful "localization" efforts, qualification of engineers hired, quality of plant equipment as well as management skills. These seem to be what any banker would like to examine before lending money to a potential borrower firm.

The producer, so selected in the examination, would have the obligation to deliver performance in exchange for a greater market share along with the "rents" from learning fast or mastering new technology. Failure to deliver performance would mean losing in the next round of competition for aid. The technocrats in the government side had the incentive for success in the program execution, because their promotion depended on the longrun performance record also.

The importance of institution has been gaining recognition in recent years. To quote Douglas North, one of the foremost advocates of institutional analysis:[45]

> Third World countries are poor because the institutional constraints define a set of pay offs to political/economic activity that do not encourage productive activity. Socialist economies are first beginning to appreciate that the underlying institutional framework is the source of their current poor performance and are attempting to grapple with ways to restructure the institutional framework to redirect incentives that in turn will direct organizations along productivity-increasing paths.

This passage provides an apt view which can explain the productivity difference between North Korea and South Korea largely due to the systemic incentive differences. The productivity difference in manufacturing is reportedly 1 to 6. This gives contrast to 1 to 2 between East Germany and West Germany. These represent a rare historical experimentation dividing up the same ethnic group into two different systems ultimately leading to different consequences after 3 decades of "experimental period".

The differential incentive structure between India and South Korea also seems to be capable of explaining the performance of productivity growth. Professor Isher Ahluwalia's TFP growth estimates for India shows a - 0.1 percent and - 0.6 percent annual average growth for the 1960-1966 and 1967-1980 periods respectively.[46] That compares with a 5.8 % growth for South Korea during the 1966-1985 period (as noted earlier). The difference of learning speed implied by these figures demands explanation. Fortunately, comparative research results are beginning to bear fruits. Staffan Jacobsson and Ghayun Alam have compared a selected set engineering industries (i.e. hydraulic excavators, machining centres, integrated circuits and plate heat exchangers) between India

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[45] Quoted from his *Institutions, Institutional Change and Economic Performance*, Cambridge : Cambridge University Press 1990, p.110

[46] I. J. Ahluwalia, "Industrial growth in India : performance and prospects", *Journal of Development Economics*, vol.23-24 (1986), p.4

and South Korea. They conclude :[47]

The Indian policy towards its industrial sector, on the other hand, was dominated by a whole set of 'restrictive' instruments which greatly limited the room for manoeuvre of private industry. The included MRTP (Monopoly and Restrictive Trade Practices Act), FERA(Foreign Exchange Regulations Act), industrial licensing policy and the policy vis- -vis Foreign technological collaboration. Indeed, the MRTP legislation aimed at restricting the growth of conglomerates with a superior risk-taking ability, precisely that form of business organization which has led development in Korea. Firm-specific and made-to-measure policies designed to help firms in their learning process seem to have been absent.

3.8 Summary

The South Korea achievement of technological capability should be interpreted as the joint work between the government and the private sector. Technological learning has been greatly enhanced by the provision of infrastructure in various forms. This intrastructure includes : research institutes, educational facilities to produce engineers and technicians, venture capital funds at "reasonable rates of interest" to reflect a longrun horizon for technological learning, along with virtually free dissemination of techno-commercial information. The role of the private sector was to take risk, learn and master new technology, whether imported or invented, and to expand export and win competition in world markets.[48]

In performing their individual roles, both the government and private enterprises, have crafted institutional devices in diverse forms. Some were longrun inventions, others very temporary and makeshift because of the urgency or lack of immediate alternative form. In any event, institutional devices must be formulated so as to increase informational efficiency, to reduce risks and uncertainties and to reduce transaction costs, so as to entice learning and risk-taking. Reward-performance linkage, and how it is organized, seem crucial for systemic efficiency in learning. This effect has to be analyzed at the firm level, and industry level, as well as in macroeconomic level. Enterprise competitiveness depends on the sum total of these learning activities at all levels. The total seems to be greater than the sum of micro components because of spacial and temporal externalities in knowledge, human capital and institutions.

This perspective suggests that some institutional arrangements or matrix could be more efficient than others. The concept of efficiency here should be rather broad to include adaptive efficiency in Schumpeterian sense.

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[47] Quoted from Staffan Jacobson and Ghayur Alam, *Liberalization and Industrial Development in the Third World : A Comparison of the Indian and South Korean Engineering Industries* New Delhi : Sage Publications India Pvt. Ltd. 1994. p.233

[48] This finding is consistent with the main theme of Michael Porter, *The Competitive Advantage of Nations*, The Free Press, New York, 1990. He concludes that the competitiveness of an enterprise depends, among others, on the support system of the economy including technological infra-structure.

Chapter 4 Conclusion

This paper sketched the phenomenal achievement in industrialization of South Korea accompanied by a high TFP growth and a structural change from labour intensive to capital-technology intensive sectors. To explain this achievement, a hypothesis has been advanced, namely, technological learning can be accelerated by: (1) knowledge accumulation, (2) human capital formation and (3) organizational or institutional ingenuity. These factors are complementary, and they remain high in the research agenda for quantification. They need to be verified as to whether the management of their complementarity constitutes a major driving force for industrialization.

It has been noted that efficient markets for knowledge, human capital, and organizational skills do not exist. The absence or imperfection of the markets renders a justification for some role to be played by the government. In the Korean case, the government has been active to craft institutional devices with the purpose of (1) reducing uncertainties and risks facing private industries (albeit selectively), (2) reducing transaction costs, (3) providing free or at nominal costs information on technological commercial opportunities, (4) providing an incentive or reward structure based on performance criteria (e.g. export records), and (5) defining rules for competition and cooperation. The state provided at least some makeshift arrangements, compensating for market imperfections and failures. The ultimate aim has been to encourage technological learning at individual, and organizational or enterprise levels, as well as the national level. Such government actions should not be termed "market repression" but rather market augmentation or market creation. Under this perspective, the debate on "market versus state" can be regarded as a false issue, so long as such a dichotomy underlines the debate.

The perspective implies that cross-country differences in productivity level can also be explained by diverse degrees of accumulation of knowledge, human capital and organizational skills. These factors deserve more attention in development economics than hitherto received. The conventional approach focussed on capital formation with little distinction between physical capital, human capital, institutional capital and knowledge capital. Such simplification in the conventional approach seems to have limited the usefulness of development economics. Clearly, the policymakers in developing countries, as well as in "transitional economies", e.g. C.I.S. countries, would benefit greatly from a new "institutional, or organizational capital" approach, as an element governing productivity growth via technological learning.[49]

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[49] The perspective sketched in this paper is consistent also with the view that an assumption of perfect market (la neo-classical school) represents an extreme case, that is, a point in a spectrum of perfect-imperfect axis (all the way to the other extreme where no market exist, e.g. Stalinist economy, primordial prehistoric economy, etc. The real world economy can be located somewhere in between where a market is defined by a collection of myriad institutional contraptions. Douglas North states succinctly : "... the market overall is a mixed bag of institutions ; some increase efficiency and some decrease efficiency." See his *Institutions, Institutional Change and Economic Performance,* New York, Cambridge University Press, 1990, p.69. See also, Herbert A.Simon, "Organizations and Markets", *Journal of Economic Perspectives,* vol.5, No.2 Spring 1991, pp 25-44, where organizational skills and efficiencies are

A further implication is that politics must come back in development economics as an important variable since crafting institutional devices involves political maneuvering. Hence, to achieve a comprehensive understanding of industrialization an analysis of the "political market", or political bargaining on institutional building, must be given proper weight in theory of development economics.[50]

emphasized.

[50] The Korean government seems also to have become a learning institution for development of institution-crafting skills. This aspect deserves a high priority in the research agenda. Useful reference for this purpose includes :

Hahn Been Lee, *Korea : Time, Change and Administration*, Honolulu, East-West Center Press, 1968 ;

Tun-jen Cheng, "Political Regimes and Development Strategies ; South Korea and Taiwan" in *Manufacturing Miracles : Paths of Industrialization in Latin America and East Asia*, edited by Gary Gereffi and Donald L. Wyman, Princeton : Princeton University Press 1990 ;

Byung Sun Choi, "Institutionalizing a Liberal Economic Order in Korea : The Strategic Management of Economic Change" Ph.D. dissertation submitted to Graduate School of Arts and Sciences, Harvard University, 1987