CONTRIBUTION OF NUCLEAR POWER TO THE NATIONAL ECONOMIC DEVELOPMENT IN KOREA

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Over the last three decades, nuclear technology development has played a vital role in the socio-economic development of the Republic of Korea. This study, being the first of its kind, focuses on quantifying the actual economic contribution of nuclear technologies to economic development by evaluating the net benefit of the nuclear power with respect to the country's Gross Domestic Product (GDP). An input-output analysis was employed as a methodological approach to analyze inter-industrial economic activities by calculating the industrial value added as a means of the economic contribution during the period of 1980 to 2005. The industrial value added of nuclear technologies was estimated from the construction and operation of nuclear power (backward-linked industrial value added) and from the industrial activities attributed to the electricity generated by the nuclear power (forward-linked industrial value added). It was found that the total net contribution of nuclear technologies as a percentage share of GDP amounted to 2.38% in 2005.

KEYWORDS : Nuclear Power, Economic Development, Input Output Analysis, GDP

1. INTRODUCTION

Nuclear technology development is not just a driving force to economic growth. It can also be a means to economic development. The purpose of this study is to review the contribution of nuclear power to the national economic development by quantifying its contribution to the GDP.

For this study, an Input-Output analysis was employed as it has merits for analyzing inter-industrial economic activities in a quantitative way. Industries or sectors in an economy are interrelated with each other and these linkages continue indefinitely. In this regard, an investment that takes place in one sector has an influence on the other sectors. For example, the operation of nuclear power plants needs support from other sectors such as fuel fabrication, construction maintenance, and so on. These sectors in turn need support from other sectors. The demand that originated from the operation of these nuclear power plants gave rise to these linkages. These inter-related activities can be traced by using an Input-Output table[1].

This study focuses on the estimates of industrial value-added, which is more readily quantifiable. The economic impact in this study covers the overall linkage effect, including both backward and forward linkages, arising from the nuclear power sector. Backward linkage occurs when the nuclear power sector stimulates other economic sectors that provide intermediate inputs to the nuclear power sector. Forward linkage effect occurs when the nuclear power sector stimulates other economic activities that are induced by the electricity generated from the nuclear power sector as an input to produce outputs.

2. OVERVIEW OF KOREAN ECONOMIC DEVELOPMENT AND NUCLEAR POWER DEVELOPMENT

Since the first industrialization process started in the 1960s, the Korean economy had been transforming at a more rapid rate than any other country in the world had ever experienced. The Republic of Korea embarked on a series of 5-year economic development plans pursuing what amounts to a classic pattern of economic development. Industrialization initially focused on light industries such as food, beverage and textiles, moving next to chemicals and metal products, and then to intermediate goods such as equipment and machinery. The focus was first on export-oriented mass production, taking advantage of Korea's abundant cheap labor and taking into account the scarcity of capital and of resources.

By the early 1970's, the trend of industrialization had

shifted to heavy industries. Imports of capital and technology were especially crucial for the development of the heavy and chemical industries, notably metallurgy (iron and steel especially), shipbuilding (and later automobiles), and construction. In contrast to the early years, the government had increasing access to private capital markets, facilitating both technology imports and investment, and a highly skilled labour force. The heavy industries were a driving force for national economic development, which helped in broadening the industrial base and essentially restructuring the economy. By 1973, the real per capita income had more than doubled the levels of that in the mid 1960s as the result of the increasing share of manufacturing to around 25% of the country's GDP.

The 1980s saw a period of adjustment in government policies and an industrial shift to more service and high-tech industries. By 1995 exports had risen to about one third of the GDP. The Korean economy grew by more than 8.7% per annum in real terms in this period. The Korean economy suffered from the Asian economic crisis in 1997 but resumed growth in 1999. In the 2000's, the Korean economy grew at the average rate of 5.2%.

During the economic development period, the demand for energy grew rapidly. It is noteworthy that throughout this period, electricity demand always grew faster than economic growth.

Korean energy policy has quite consistently focused on supplying energy in order to fuel rapid industrialization and strong economic growth. This growth was driven by the expansion of energy-intensive industries in the 1980s and 1990s, which were fostered by concentrated development policies and resulting in a very higher national average standard of living.

All of this was done with limited indigenous coal and hydro energy resources, and hence before the advent of the nuclear power industry, Korea needed to import 97% of its energy. 80% of electricity generation was dominated by imported crude oil, creating severe economic problems as oil and energy prices rose in the 1970s. Faced with the need for further increases of increasingly expensive fuel imports to supply its rapidly growing industrial, transportation, and electricity sectors, the government opted to diversify its energy sources by focusing on nuclear power as a more technology-oriented, rather than a resource-oriented way, to reduce reliance on imported energy. The energy and electricity intensive intermediate and heavy industries provided a ready market and a rationale for domestic nuclear power that would permit their continued competitive output and growth without dramatically increasing energy imports. In reality, the development of the nuclear industry created domestic markets for equipment, the metallurgical and construction industries, electronics, and the business service sectors including finance and insurance, which in effect created a significant inter-sectoral symbiosis.

The electricity sector thus provided more than just electricity to the fledgling industrial sector. "The earliest and largest modernization projects in post-war South Korea were power plants. Large domestic conglomerates were selected to construct, engineer and manage huge coal, oil and nuclear power plants" (Byrne et.al, 2004)[2]. Between 1960 and 1987, Korea built 20.6 GW of new generation capacity (14.8 GW of fossil-fuelled plants and 5.8 GW of nuclear plants). Construction of these plants and the gradual increase in domestic contribution helped in establishing and expanding the industrial base of the economy. Conversely, "South Korea's spectacular economic growth was, in part, based on a formula of doubling electricity capacity every ten years" (Byrne et.al, 2004)[2].

Nuclear technology in the Republic of Korea has been an integral part of the country's socio-economic development over the past decades, and its evolution from an importer to a potential exporter of nuclear plants and nuclear technologies provides spin-offs to technological innovation as well as to the environmental benefits in terms of avoiding GHG and other pollution in the context of achieving sustainable development.

Nuclear technology was chosen to diversify the energy supply in response to the economic development setbacks resulting from the oil crises of the 1970's and 1980's. A strong commitment by the government to develop a nuclear power programme received impetus from three main factors: lack of domestic energy resources, favourable world nuclear markets in the 1980's, and having an active and concerted government cooperating with a dedicated nuclear work force.

Korea's commitment to nuclear power and its need for initial imports of nuclear technology were greatly aided by the depression of the world nuclear industry in the 1980's, which was the result of the collapse in international oil prices in the mid 1980's and the growing excess generating capacity of the OECD countries due to the delayed impact of efficiency improvements and economic restructuring prompted by the oil price hikes of the 1970s. These changes were also based on the public's reaction to the Three Mile Island and Chernobyl accidents and the resulting growth of the anti-nuclear-movement. This created a buyer's market and made it possible for Korea to conclude technology transfer agreements with foreign suppliers under favourable conditions.

Strong government commitment was essential first to foster and then to marshal Korea's well- educated human resources to successfully implement the national nuclear technology self-reliance programme. The Korean nuclear scientists and engineers that were engaged in overseas nuclear power programmes were attracted back to Korea to play key roles in the localization of nuclear power technology development and the enhancement of direct national participation into nuclear power projects.

National participation in a project generally means

the use of locally produced material and domestic manpower resources without downgrading the quality and safety aspects of the project nor jeopardizing the schedule of project execution. Meaningful national participation in a nuclear power and plant construction industry requires the existence of a capable construction industry, and medium and heavy manufacturing, including cement, steel, machinery and equipment and chemicals. This also requires competency in other services such as civil engineering, quality assurance and control and testing, and specialized manpower training including managerial skills.

The active production history of nuclear energy development started in 1978 when the Kori-1 nuclear power plant, built on a turn-key basis, first began commercial operation. It was an imported reactor with imported service and support, with little participation from the domestic industries and limited use of local labour or construction materials (for on-site non-specialized purposes). In 1985, the government started implementing an incremental national self-reliance policy and began allocating some responsibilities to local organizations. At first these responsibilities were limited to civil engineering and design, construction, and plant engineering, manufacturing some equipment and non-critical components for plant balance, and managing projects. With the construction of the Yonggwang 3 and 4 NPPs in 1989, domestic nuclear industries became the prime project contractors with only limited technological support and technology transfer from foreign subcontractors. Equally important, local manufacturers extended their normal product lines to incorporate nuclear designs and standards, and special factories were set up locally to manufacture heavy and specialized nuclear components.

Korea has rapidly accumulated extensive experience in nuclear sector development and planning and nuclear power plant construction and operation. Over the past three decades, Korea has become one of the world's leading nuclear power countries, with 20 Nuclear Power Plants (NPPs) in commercial operation in 2005, with a total net generating capacity of nearly 17.5 GW, supplying approximately 18% of Korea's total primary energy and more than 40% of the nation's electricity.

Korea is already exporting reactor components, and is now also in a position to supply plants for export. Korea has already developed the Korean Standard Nuclear Reactor (KNSP), a PWR that is being used in Ulchin-3, -4, -5 and -6, and Yonggwang-5 and -6. They are also constructing a Korean Advanced Pressurised Reactor (APR 1 400) for Shin-kori 3 and 4, and the Optimized Power Reactor 1 000 (OPR 1 000). Korea may therefore well be a strong competitor in the vendors and plant suppliers market in the near future. Based on domestic technology and more than twenty years of experience in the construction and operation of nuclear power plants, the Korean nuclear industry is in fact actively developing an overseas nuclear power business aimed at supplying engineering and technical services, components, construction services, or even the complete building of a KSNP. The overseas engineering and technical services will cover the plant life cycle including project planning, project management, equipment procurement, commissioning and start-up, operation and maintenance, as well as replacing major equipment, such as steam generators.

3. VALUE-ADDED FROM THE CONSTRUCTION AND OPERATION OF NUCLEAR POWER TO NATIONAL GDP

This section focuses on quantifying nuclear power's value-added contribution over time to the value of industrial output in Korea, and hence ultimately to GDP. The Input-Output analysis[1] in this study was used to quantify the purchases of goods and services that any one industry - in this case nuclear power - makes from other industries, and the extent to which these purchases contribute to the final value of the output in each of these other industries. This contribution is generally calculated in terms of output, from which value added is derived. The time period studied is 1980 to 2005 in 5-year increments.

The economic impact of the nuclear power sector is calculated here only in terms of industrial output and value-added as derived using I-O analysis. The analysis focuses on the inter-industry impact of nuclear power plant construction and operation, defined first as the share that these purchases contribute to final demand for industry output, and ultimately by the contribution of nuclear power to the value added of this increased output [4].

3.1 Structuring the I-O Tables

In order to make the study more adequate, a modified I-O table was created that derived from the Korean National I-O Table, published by the Bank of Korea. The first major step was to review, refine and reconstruct the national I-O tables to accommodate the level of detail needed for this analysis, and to better trace those activities involving nuclear power. This involved constructing time series and I-O tables for industrial statistics that complied with the 3-digit International Standard Industry Code (ISIC) level. These efforts also needed the national team's extensive and thorough understanding of the Korean economy, as well as a knowledge of which industries have been or are now associated with nuclear power, and the linkages between them. The approach and structure of this analysis were validated and calibrated by KAERI(Korea Atomic Energy Research Institute) using the nuclear electricity generation industry for the year 2000 as a test case.

[1] I-O analysis was pioneered Wassilief Leontief (1930) with an I-O model at the national level [3].

The original National I-O Table had 4 levels of sector classifications: 404 sectors covered in the basic survey, regrouped first into 168 sectors, then into 77 larger sectors and finally into 28 major industrial classifications. To better reflect the industrial linkages of the various nuclear technologies for this study, the Korean National I-O Table

Table 1. Reorganized 36 Sectors in the National I-O Table

No.	Sector name	Related nuclear activity
01	Agriculture, forestry, and fisheries	Food processing
02	Mining and Quarrying	
03	Food, beverage and tobacco	Food processing
04	Textile products & leather products	Non-destructive testing
05	Wood and paper products	Non-destructive testing
06	Printing, publishing and reproduction of recorded media	
07	Petroleum and coal products	
08	Chemicals and allied products	Radiochemistry
09	Inorganic basic chemical products	Nuclear fuel fabrication
10	Non-metallic mineral products	Non-destructive testing
11	Primary metal products	Non-destructive testing
12	Fabricated metal products	Non-destructive testing
13	General machinery and equipment	Manufacturing of main components and other machinery
14	Electronic and other electric equipment	Manufacturing of instrument and control devices
15	Precision instruments	Non-destructive testing
16	Transportation equipment	
17	Furniture and other manufacturing products	
18	Water power generation	
19	Thermal power generation	External electricity supplied to nuclear power plant in operation
20	Atomic power generation	Nuclear power plant operation
21	Self-power generation	
22	Gas and water supply	
23	Repair construction	Construction related to the operation and maintenance
24	Electric power plant construction	Construction of new nuclear power plant
25	Wholesale and retail trade	
26	Eating and drinking places, and hotels and other lodging places	
27	Transportation and warehousing	
28	Communications and broadcasting	
29	Finance and insurance	Finance and insurance of nuclear power plant
30	Real estate agencies and rental	Siting
31	Business services	Architecture engineering
32	Public administration and defence	
33	Educational and research services	Research reactors
34	Medical and health services, and social welfare	Nuclear medicine
35	Social and other services	
36	Dummy sectors	

was modified to comprise 36 sectors, with the industry sector divided into 16 sectors. All industry data from the original 28 industry sectors were first transformed to the 3-digit level of ISIC and then re-grouped into the newly structured 16 industry sectors. Since all coefficients in a given sector or grouping of sectors were additive, this restructuring of the original table to a simpler form did not invalidate any of the input coefficients taken from the original table.

The economic activities associated with the nuclear power sector were broken down and classified as construction, nuclear fuel fabrication, operation and maintenance. In the case of plant construction, the activities were divided into civil construction, architecture engineering, and component manufacturing. Component manufacturing was further divided by main component (instruments, other machinery, and instrument and control devices). Additional sector classifications were made for finance and insurance, and external power supplies, which are needed for the construction and operation of a nuclear power plant.

The analysis and the presentation of results for construction and operation are not entirely parallel, due to differences in data availability. Data on expenditures and inputs for construction as provided by KHNP(Korea Hydro & Nuclear Power Co., LTD) were sufficiently detailed for it to be used directly to calculate the final demand in other sectors. In the case of operations, intermediate inputs were directly obtained from the national I-O table, and then used to calculate the final demand generated by the nuclear power operations from each other sector, and subsequently to estimate the output and value added of plant operation.

I-O tables are generally constructed using current prices, with the price of each input indirectly incorporated into and hence reflected in the input coefficients. Given the plethora of data involved in constructing an I-O table, and given the intricacy of some of the I-O inter-sectoral relations, adjusting the equations to produce constant prices would complicate and weaken the analysis. Consequently, all monetary values in this study are given in current won.

The names of each of the reorganized national I-O sectors, and the related nuclear activities for the sector, are shown in Table 1.

3.2 Nuclear Power Plant Construction

The raw data on nuclear power plant construction costs provided by KHNP were re-classified into initial fuel, building and structures, machinery equipment, architect and engineering services, interest during construction and owner's cost. These costs can be viewed as expenditures, and were used in the formulation of the I-O analysis as estimates of final demand created by the activities associated with the construction of nuclear power plants.

These cost items were then matched to the corresponding sectors in the reorganized I-O table. Initial fuel was matched to inorganic basic chemical products, building and structure to electric power plant construction, machinery equipment to electronic and other electric equipment, architect and engineering to business services, and owner's cost was spread across several sectors including business services, furniture and other manufacturing, finance and insurance. These allocations are summarized in Table 2.

Based on this allocation, the contribution of nuclear construction activities to the final demand in each relevant sector was calculated. Fig. 1 shows the contribution and the growth in importance of nuclear plant construction to each of the relevant and affected industrial sectors. The amount of nuclear power's final demand contribution directly depended on the magnitude of construction activities carried out in each period.

The yearly final demand in selected industries, which originated from nuclear power plant construction is a driving force to stimulate economic activities.

The stimulating economic activities can be calculated by the following equation, which is provided by Input-Output analysis[5].

$$X = (I - A)^{-1} Y$$

Where, I = Identity matrix, X = Induced output, A = Input coefficient, Y = final demand originated from nuclear power plant construction.

Table 2. Matching NPP Construction Costs to Corresponding I-O Sectors

Collected cost items	Sectors in I-O
Initial fuel	Inorganic basic chemical products (9)
Building, structures	Electric power plant construction (24)
Machinery equipment	General machinery and equipment (13), Electronic and other electric equipment (14)
Architect/Engineering	Business services (31)
Interest during construction	Finance and insurance (29)
Owner's cost	Business services (31), Furniture and other manufacturing (17), Finance and insurance (29)

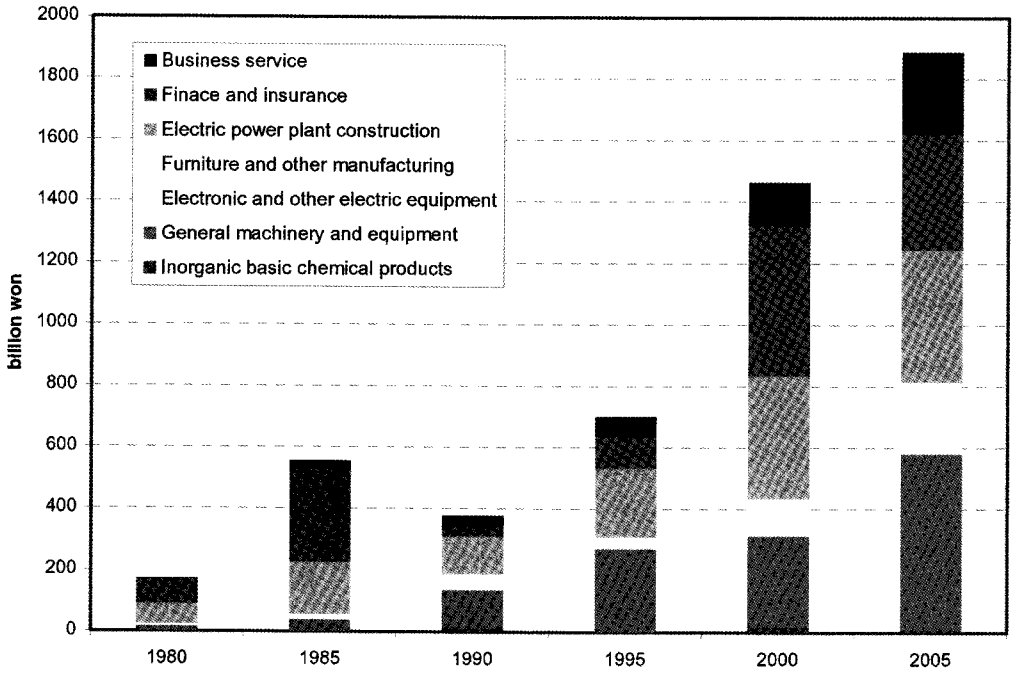

Fig. 1. Creation of Yearly Final Demand in Selected Industries by Nuclear Power Plant Construction (Billion Won)

3.3 Nuclear Power Plant Operation

As with construction, the I-O analysis for nuclear power plant operations requires yearly final demand in each relevant industry generated by operating plants through expenditures for goods and services. The analysis of this annual final demand starts from the intermediate inputs to the nuclear sector taken directly from the reorganized I-O table in this study. Based on these intermediate inputs, some 29 sectors (out of 36) were identified as providing inputs to nuclear plant operations. The main ones include inorganic basic chemical products (for nuclear fuel fabrication), atomic power generation (input for internal power use), repair construction, finance and insurance, business services (all needed for plant maintenance), and educational and research services (including R&D activities in nuclear science and application). The uranium needed to support fuel fabrication services is imported, and is shown in the reorganized I-O table under the inorganic basic chemical products sector (9).

To be able to isolate the particular impact of nuclear plant operations among the inter-industry linkages of I-O table, the nuclear sector had to be treated conceptually as exogenous. This required a small modification of the model, and is expressed in the analysis as follows[5]:

$$X = (I - A^*)^{-1} A_g X_g$$

Where, X = Induced output, A^* = Input coefficient without nuclear sector,

A_g= Input coefficient of nuclear sector, X_g= Output of nuclear sector

$A_g X_g$ is the domestic intermediate input to the nuclear sector in the I-O table, thus defining final demand attributable to nuclear operations in the model. The values for $A_g X_g$ (i.e., for the contribution of nuclear plant operations to each sector) thus obtained in the reorganized I-O table are shown in Table 3.

3.4 The Effects of Nuclear Power Plant Construction

The contributions to outputs and value-added of nuclear power plant construction in each period are shown in Fig. 2.

The I-O analysis results show that the industrial sectors affected by nuclear power plant construction varied as the character of the construction changed from turn-key plants to greater technological self-sufficiency. For example, before 1990, there were only two principal relevant industrial sectors: electric power plant construction, and finance and insurance. After 1990, as Korea approached technological self-sufficiency in nuclear power plant construction, the number of relevant dominant affected sectors increased to include primary metal products, general machinery and equipment, electronic and other electric equipment, and business services. In fact, the general machinery and equipment sector were the most dominant sectors for the years 1990 and 1995, reflecting large expenditures in these sectors for new plants.

The spillover effects of localising plant construction

Table 3. Breakdown of Nuclear Plant Operations as Domestic Intermediate Input in the Reorganized I-O Table (*million won*)

	1980	1985	1990	1995	2000	2005
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	30	76	1 330	2 274	3 112
5	0	25	74	185	323	358
6	104	643	1 334	1 773	2 153	3 045
7	193	3 426	7 107	9 440	21 621	23 911
8	0	111	1 272	1 858	2 627	3 270
9	4 357	25 958	53 754	170 342	445 846	405 139
10	0	66	721	405	2 662	3 711
11	0	26	35	6 710	7 700	10 799
12	0	604	2 437	4 023	9 933	14 807
13	0	1 937	4 929	12 065	39 286	54 457
14	595	4 630	18 542	33 254	91 882	102 087
15	0	823	3 233	2 195	7 493	7 914
16	50	414	1 552	2 440	1 228	1 721
17	896	38	135	1 414	942	1 589
18	8	70	7 953	7 244	2 548	3 558
19	97	629	71 576	152 619	78 755	104 983
20	11	284	79 528	96 303	100 769	126 081
21	0	0	0	0	0	0
22	39	186	535	480	400	939
23	870	15 094	132 230	286 238	427 227	517 382
24	0	0	0	0	0	0
25	1 478	6 064	27 617	12 266	28 510	31 368
26	0	0	0	0	0	0
27	184	1 056	4 801	8 610	12 727	35 849
28	157	1 006	2 545	14 082	23 168	28 867
29	3 392	15 218	36 764	46 801	223 453	261 556
30	306	1 314	2 820	2 458	4 103	5 635
31	78	5 928	35 471	56 318	144 434	225 961
32	0	0	0	0	0	0
33	157	1 644	3 815	92 797	148 772	253 768
34	8	550	645	4 294	25 015	57 044
35	0	327	788	1 881	4 823	6 764
36	3 826	9 169	31 463	30 300	55 752	67 664
Total	**16 806**	**97 270**	**533 752**	**1 060 125**	**1 916 426**	**2 363 141**

activities are also reflected in industrial sectors not constituting direct final demand for nuclear sector. Most important of these is the primary metal products sector (11) (including steel), which has shown the greatest impact

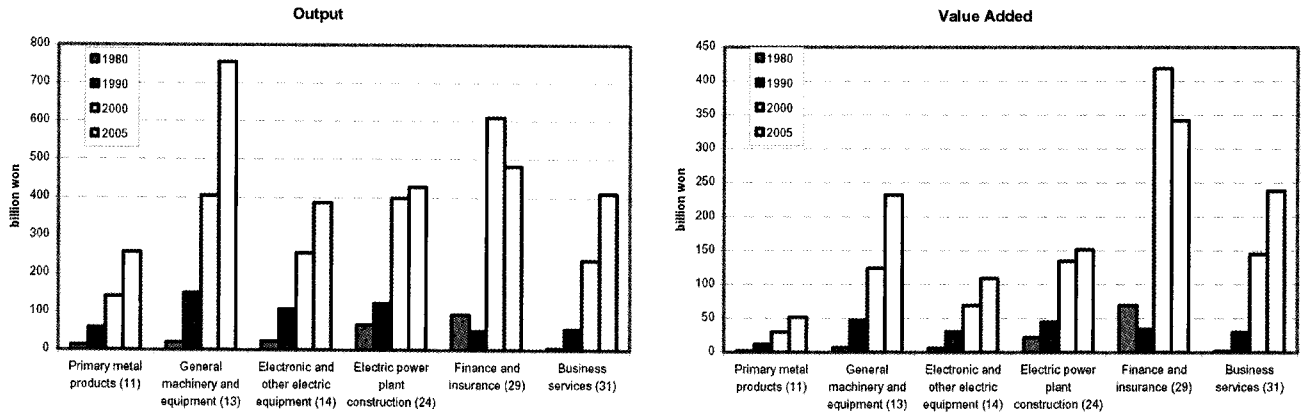

Fig. 2. Industrial Output and Value Added Contributions of Nuclear Power Plant Construction in Major Relevant Industries

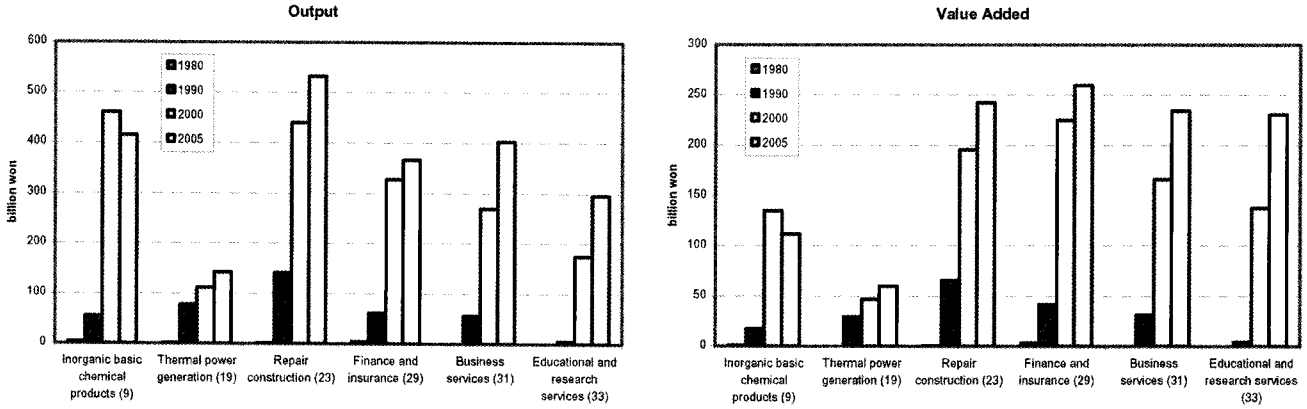

Fig. 3. Industrial Output and Value Added Contribution of Nuclear Plant Operations in Major Relevant Industries

since 1990. This sector has been given a great indirect boost providing input to the construction of nuclear power plants, by, for example, developing special quality steel producing capabilities applicable to other sectors.

3.5 The Effects of Nuclear Power Plant Operations

The economic linkage effects of nuclear power plant operations show the same evolution as the construction phase, which is namely a shift in affected sectors as the number of plants and their degree of localization both grew. Before 1990, finance and insurance, as well as inorganic basic chemical products were the sectors most affected by the operation of nuclear power plants. This is primarily due to the expenditures for nuclear fuel and interest payments for heavy loans made during that period. Since 1990, however, the construction sector (for repairs, extensions and maintenance) together with inorganic basic chemical products have become dominant, as nuclear power generation increased significantly, requiring inputs from these sectors for operation of the plants.

The output and value added contributions of nuclear power plant operation are shown in Fig. 3.

There are three observations: First, thermal power generation plays a supporting role in the continuous operation of nuclear power plants, either to supply electricity to nuclear plants during shut down periods (for overhaul and maintenance) or to serve as an alternative source of electricity as an operational safety measure. In some years this contribution has been more significant than others, largely depending on the timing of scheduled outages. Second, the finance and insurance and the business service sectors were found to have a lower value added from the plant operation phase than from the plant construction phase, despite the repayment of heavy construction loans extending into the operational phase. Finally, and not surprisingly, total demand for goods and

Table 4. Summary of the Total Nuclear Power Sector Contribution to GDP *(billion won)*

		1980	1985	1990	1995	2000	2005
Gross output	Construction	287	938	748	1 514	2 665	3 585
	Operation	191	1 277	3 571	5 667	11 081	13 865
Value added	Construction	135	466	283	615	1 180	1 491
	Operation	148	1 018	2 414	3 581	7 281	9 163
GDP		37 116	78 848	178 317	375 803	599 645	810 516
Value Added Contribution to GDP		0.8%	1.9%	1.5%	1.1%	1.4%	1.3%

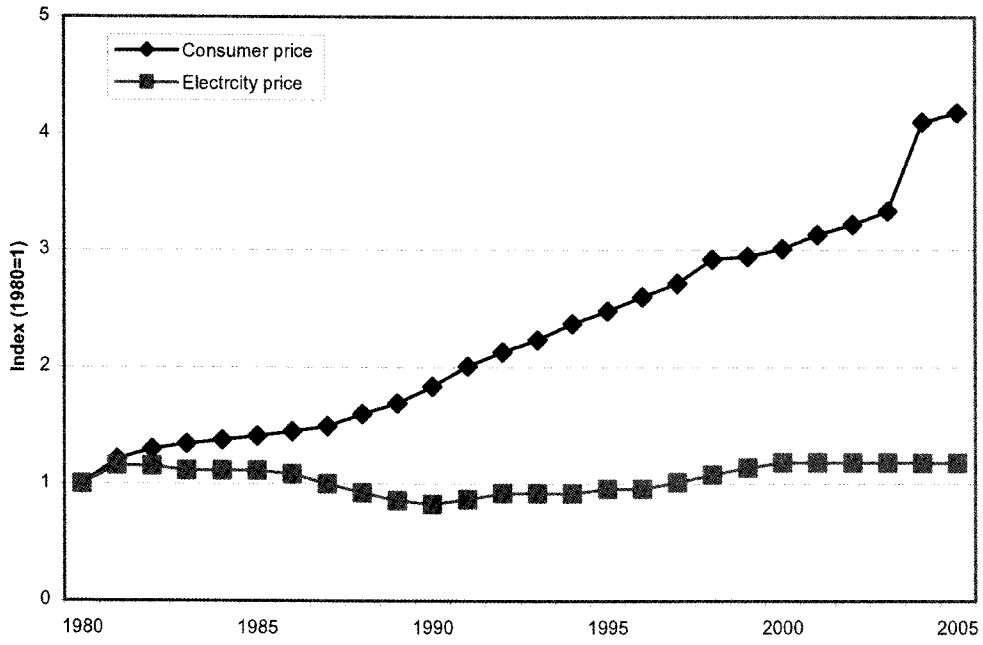

Fig. 4. Electricity Price vs. Consumer Price Index

services by the nuclear sector increased as time went on, reflecting the growth of nuclear power generation in Korea.

3.6 Summary of Value-Added from the Construction and Operation of Nuclear Power to the National Economy

Table 4 shows the total estimated economic contribution of nuclear power to GDP.

In 2005, the combined value added for both construction and operation of nuclear power plants were estimated to amount to being 1.31% of GDP in Korea, with 1.13% from operations and the remaining 0.18% from construction. The overall value added from nuclear plant operations was greater than for construction for the whole period studied except for 1980, when nuclear power generation accounted for only a small portion of electricity supply. This result is not surprising: the economic impact of construction is primarily limited to the period when the construction is done, while the economic impact of plant operations continues throughout the life of the plant.

4. VALUE-ADDED FROM THE ELECTRICITY SUPPLY OF NUCLEAR POWER TO NATIONAL GDP

Nuclear generated electricity as an input to all the economic activities contributes to the economic development (forward-linked industrial value added).

Electricity is used by many other sectors as input to their outputs, which in turn, are used by the other sectors as inputs to their outputs. In this way, the linkage continues indefinitely. This contribution is referred as supply inducements effect from nuclear power generation. In addition, there is another economic contribution of nuclear technology resulting from the stabilization of electricity price.

Table 5 shows that nuclear power has proved itself to be a competitive power supply technology in terms of generating costs.

In 2005, the cost of nuclear generation (39.1 KRW/kWh) was less than that of coal (48.6 KRW/kWh). Both nuclear and coal power generation cost was far below than oil and LNG-fired generation cost, and even below the system average generation cost of 50.67 KRW/kWh. Since 1980, the growing share of low cost nuclear generation has contributed to the stability of electricity prices. The average price of electricity actually fell from 1982 to 1992, at a time when consumer prices generally rose by as much as 9% annually (Figure 4).

Lowering electricity price is considered as an economic contribution to national economy and it is referred as the electricity price stabilization effect induced from nuclear power generation.

In this section both supply inducements effect and electricity price stabilization effect from nuclear power generation are analyzed[2].

The supply inducements effect from nuclear power generation is shown in Table 6.

Table 6 shows that the supply inducements multipliers are in the range of 2.7 - 3.1 varying from year to year, which implies that the total supply inducements over the periods from 1998 to 2006 amounted to 111 trillion won. The supply inducements was about 15 trillion won in 2005 and about 16 trillion won in 2006.

Electricity price stabilization effect from nuclear power generation was estimated based on required data on the potential increasing rate of electricity price in case the existing nuclear power would be replaced with fossil power plants. The elasticity of GDP, which measures the degree of responsiveness of GDP to changes in electricity price was also analyzed.

The electricity price stabilization effect from nuclear power generation is calculated as:

[increasing rate of electricity price in case the existing nuclear power would be replaced with fossil power plants] × [elasticity of GDP with respect to electricity price] × GDP

The result of electricity price stabilization effect from nuclear power generation is shown in Table 7 for the periods from 1998 to 2003.

The periods are then extended to 2005 by applying the average values observed during the periods. As a result, the electricity price stabilization effect from nuclear power generation in 2005 was estimated to 2.2 trillion. It can be transferred to 5.1 trillion in terms of total output[3].

5. SUMMARY OF THE TOTAL NUCLEAR POWER CONTRIBUTION TO THE NATIONAL ECONOMY

The total estimated contribution of nuclear power to GDP is shown in Table 8.

The total contribution of nuclear power construction and operation expressed in percentage share of its value

Table 5. Comparison of Generation Cost by Source in 2005

(won/kWh)

Nuclear	Coal	Oil	LNG	Average
39.1	48.6	91.1	87.1	51.0

[2] Both effects were referred to a report entitled "The role of nuclear power for sustainable development", KAERI, 2007 (KAERI/RR-2886/2008)[6]

[3] The electricity price stabilization effect is expressed in value added because the effect is calculated based on GDP. Value added coefficient of 0.43, which is the average coefficients for value added, was used to convert the value added to total output.

Table 6. Supply Inducements Effect from Nuclear Generation

(100 million won)

	'98	'99	'00	'01	'02	'03	'04	'05	'06	Total
Sales amount of nuclear power	28,697	34,641	40,723	42,238	44,761	49,017	49,063	54,521	53,953	397,614
Supply inducement multiplier	3.08	2.91	2.73	2.80	2.69	2.70	2.72	2.74	2.88	-
Supply inducement	88,386	100,805	111,173	118,266	120,407	132,345	133,451	149,387	155,384	1,109,604

Table 7. Electricity Price Stabilization Effect from Nuclear Power Generation[4] (*100 million won*)

Year	1998	1999	2000	2001	2002	2003
Increasing rate of electricity price* (A)	9.4%	6.0%	5.5%	8.01%	7.5%	8.82%
Decreasing % of GDP due to the increase of electricity price(B) = (A) × 0.0363645**	0.342%	0.218%	0.200%	0.291%	0.273%	0.321%
GDP(C)	4,841,028	5,294,997	5,786,645	6,621,226	6,842,635	7,246,750
Contribution from nuclear power = (B) × (C)	16,548	11,553	11,574	19,286	18,662	23,243
Contribution from nuclear power to GDP	0.342%	0.218%	0.200%	0.291%	0.273%	0.321%

*: increasing rate of electricity price in case the existing nuclear power would be replaced with fossil power plant
**: elasticity of GDP with respect to electricity price

Table 8. Summary of the Total Nuclear Power Contribution to the National Economy (*billion won*)

	2000	2005
Construction	1,180	1491
Operation	7,281	9163
Value Added Contribution from Construction and Operation to GDP	1.46%	1.31%
Supply inducements	4780	6424
Electricity price stabilization	1157	2222
Value Added Contribution from Electricity Supply to GDP	1.03%	1.07%
Total Value Added Contribution to GDP	2.49%	2.38%

added to GDP in 2005 was estimated to be 1.31%, with 1.13% from operations and the remaining 0.18% from construction. The overall value added from nuclear plant operations was greater than that of construction for the entire study period, with the exception of 1980 when nuclear power generation accounted for only a small portion of electricity supply. This result is not surprising: the economic impact of construction is primarily limited only to the construction period, while the economic impact of plant operations continues throughout the life of the plant.

The combined value added for both supply inducements and electricity price stabilization from nuclear power generation were estimated to be 1.07% of the GDP in 2005, with 0.79% from supply inducements and the remaining 0.27% from electricity price stabilization attributable to nuclear power generation, respectively.

In sum, the total contribution from nuclear power to the national economy was estimated to be 2.38% of the GDP in 2005.

[4] Increasing rate of electricity price in case the existing nuclear power would be replaced with fossil power plant and elasticity of GDP with respect to electricity price were referred to a study entitled "The effect of nuclear power industry on the electricity price in Korea", Samil pricewaterhouseCoopers, 2004.8[7].

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