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Impact of Consumption Pattern Changes on Environmental Pollution in Korea*

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Environmental pollution is generated through the production process or through the consumption process of goods and services. Since production is induced mainly by consumption there is a need to concentrate on the impacts of consumption activities in environmental pollution rather than the production activities. This paper focuses on the impacts of consumption pattern changes on environmental pollution in Korea as few studies have addressed this issue. This paper employed a newly-developed estimation procedure and a newly-compiled environmental data base in order to accomplish this objective. On the basis of such establishments, both an air and a water pollution material discharge matrix were compiled for 105 sectors. A conclusion is reached that the change in consumption patterns such as the increasing shares of the service and IT sector's consumption are expected to decrease both air and water pollution material discharges per unit consumption while the growing trend of consumption in an aging population is likely to generate limited change both in air and water pollution emissions.

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1. INTRODUCTION

Environmental pollution is generated either through the production process or through the consumption process of goods and services. Although some kinds of environmental pollution stem from natural phenomena there exists no method to control them. There is a need to concentrate on the impact of consumption activities on environmental pollution than those of production activities since production is induced mainly by consumption. Environmental studies have dealt with the latter rather than the former with Korea being no exception in this respect.

The process of economic development in the early stages aggravates environmental pollution but improves it in the later stages. What is of interests is whether the recent economic development stage and corresponding economic activities (both in production and in consumption) contribute to the amelioration of environmental quality in Korea.

Studies show that Korea has experienced a remarkable change in consumption patterns. Koreans now consume more IT products and service-related products than before. The increase of an aging population has been another key factor in influencing consumption patterns and few studies have analyzed such issues. Data shortage or unavailability has been a major impediment to such efforts. This paper will clarify issues and initiate environmental impact studies of the consumption pattern changes by creating an appropriate data base.

Related studies have carried out recently by Sung Woo Kim (1998) estimated the direct and indirect pollution emissions induced by final demand by utilizing 24-37 sector environmental pollution vectors. Based on Kim's estimation Gi Bok Chang *et al*. (2000) analyzed the impacts of growing knowledge-based industries on environmental pollution while Kwang Im Kim *et al*. (2001) analyzed environmental influences of expanding service sector industries. In another situation Dae Mun Park (2002) tabulated 24 sector environmental pollution vectors and calculated air pollution emissions in 1990 and 1995. This purpose was to figure out major factors of change in air pollution emissions between the two periods. Preceding studies based on 20-30 sector I/O tables were not substantial enough to take consumption pattern changes into consideration and unable to consider such major patterns of change in consumption as the increasing weights of IT goods and service sectors.

This paper creates a new environmental data base and employs a newly-developed estimation technique in order to overcome the limitations of preceding studies. Large scale I/O tables are compiled to consider recent major changes in consumption patterns and to analyze the impacts on environmental pollution in detail. A new line of analytic model will be introduced in the following section. Section 3 provides explanations on tabulation processes of environmental pollution emission matrices. Environmental impacts of consumption pattern changes based on the newly compiled environmental pollution I/O tables will be analyzed in section 4. The final section provides a summary and conclusions.

2. A MODEL FOR ENVIRONMENTAL POLLUTION STUDIES

The following is a standard I/O model designed to analyze the effects of changes in final demand such as consumption, investment, and exports in related industries.

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

where, X: production,

I: identity matrix,

A: input coefficients,

Y: final demands.

The objective of this paper is to analyze the impacts of private consumption pattern changes and the equation (1) is reformulated such

$$X = (I - A)^{-1} C. \quad (2)$$

where, C: private consumption.

$(I - A)^{-1}$ in equation (2) is the production inducement coefficient matrix which represents production units required to meet the unit increment of private consumption.

In order to measure direct and indirect pollution discharges induced by private consumption there is a need to compile an environmental pollution emission matrix. Once the matrix of air pollution and water contamination is compiled it is possible to multiply it by the Leontief's inverse matrix and private consumption vector so to estimate pollution emissions induced both directly and indirectly in the production process. To estimate the total environmental impacts induced by private consumption there is a need to compile the pollution material emission matrix induced by consumption separately and then add it to the production-induced pollution material emission matrix.

The following is the functional representation of the above arguments.

$$v^* = vX. \quad (3)$$

v^* represents the quantity of environmental pollution substances, while $v = \left[v_{kj} \right]$ represents the pollution emission matrix. v_{kj} is the quantity of the kth pollution material discharge induced by unit production in the jth industry. This matrix is compulsory in addition to the general standard I/O tables.

From the substitute equation (2) for matrix X in equation (3), the following is derived,

$$v^* = v(I - A)^{-1} C. \quad (4)$$

$v(I-A)^{-1}$ in equation (4) is defined as the environmental pollution material discharge inducement coefficient matrix, in such a way that v^* in equation (4) represents the quantity of pollution material emissions induced directly and indirectly by private consumption.

To compile independently the environmental pollution material discharge matrix, $w=\left[w_{kj}\right]$, (where w_{kj}) represents the quantity of the *k*th pollution material discharges induced by unit consumption in the *j*th industry. The final and total environmental impacts induced by private consumption will be measured by considering both v_{kj} and w_{kj} .

3. COMPILATION OF ENVIRONMENTAL POLLUTION DISCHARGE (EMISSION) MATRIX

3.1. Sector Classification

In order to meet such needs industries are broken down by using the data which is broken down in detail comparably such as “Clean Air Policy Support System”[1) and “Generation and Treatment of Industrial Waste Fluid” and estimating by using I/O table. First there is a need to break down industries in detail to capture characteristic pattern changes in consumption and to evaluate in detail their impacts on the environment.

The sector classifications are carried out based on the sector classifications of 1990-1995-2000 jointing constant I/O tables and the following principles:

1) Agriculture, forestry & fishery, mining, construction, and most manufacturing industries were classified based on the medium-sized sector classification (77 sectors).
2) Service industries were classified based on the small-sized sector

[1)] This system makes it possible to estimate the amount of air pollutants’ emission which is generated through no-fuel consuming production process.

classification (168 sectors), considering the fact that shares in private consumption expenditure have increased recently.

3) Energy source industries that produce petroleum and coal products were classified based on the basic sector classification (352 sectors).

4) As a result a 105 sector classification standard; including 4 agriculture, forestry & fishery sectors, 4 mining sectors, 56 manufacturing sectors, 6 electric, gas & water services, and construction sectors, 32 service sectors, and 3 miscellaneous sectors was adopted.

3.2. Compilation of Pollution Material Emission Matrix

Based on the 105 sector classification standard, the pollution material emission matrix was compiled in relation to air and water pollution materials created in the production and consumption process of goods and services.[2)]

3.2.1. Air pollution material emission matrix

The air pollution material emission matrix was compiled based on the data of "Clean Air Policy Support System"[3)] from the Ministry of Environment and the 1990-1995-2000 jointing constant I/O tables of the Bank of Korea. Only four pollution substances (CO, NO_X, SO_X, $PM10$) were investigated. TSP was excluded from consideration due to the probable overlapping with $PM10$.[4)] Pollution materials were measured and tabulated separately for the 105 classified sectors depending on induction of the production or consumption process. Air pollution material emission matrices were compiled based on these estimates.

3.2.2. Water contamination material discharge matrix

Data compiled by the Ministry of Environment, *Generation and Treatment*

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2) The estimated quantity of environmental pollution material discharges does not represent total pollution materials created, but rather final pollution emissions discharged into nature after being filtered through pollution reduction devices.

3) For details, see table A1 "Clean Air Policy Support System" in Appendix.

4) $PM10$ implies the quantity of dust of size 10μm or smaller in diameter.

of Industrial Waste Fluid[5] were utilized for the water contamination measurement. But only industrial waste fluid was considered (while livestock waste water and life sewage were excluded from the tabulation) due to a basic data shortage problem.

Pollution sources for consideration were confined to waste water discharge and BOD load of discharge. In addition, only the production-induced waste water discharge matrix was compiled for the 105 classified sectors, since the data for the consumption-induced waste water discharge matrix was unavailable. This analysis on consumption-induced pollution was excluded from consideration.

4. IMPACTS OF CONSUMPTION PATTERN CHANGES ON ENVIRONMENTAL POLLUTION

4.1. Environmental Pollution Discharges by Consumption Patterns

Two steps were taken to analyze the impacts of consumption pattern changes on environmental pollution. To measure pollution discharges induced by consumption patterns based on the 2000 data base is the only possible one to due to the data available in this study. The second step is to perform a simulation study based on two scenarios, aiming at analyzing the probable impacts of consumption pattern changes on environmental pollution.

The 105 sector pollution discharge vectors were compiled both for air and water pollution. Compiled vectors were then aggregated into three complementary sets of consumption patterns in; service sector versus non-service sector consumption expenditure, IT sector goods versus non IT sector goods consumption expenditure, and the consumption expenditure of the aging versus the non-aging population.

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[5] For details, see table A2 "Generation and Treatment of Industrial Waste Fluid" in Appendix.

Table 1 Air Pollution Material Emission Inducement Coefficients by Consumption Patterns

(unit: ton / billion won)

Consumption Patterns	Shares in 2000 (%)	CO	NO_X	$PM10$	SO_X	Total Emissions
Service (a)	68.0	0.807	1.393	0.082	0.472	2.753
Non-Service (b)	32.0	2.723	1.298	0.102	0.895	5.019
(a/b)*100(%)		29.6	107.3	80	52.7	54.9
IT (c)	8.2	0.207	0.26	0.02	0.186	0.672
Non-IT (d)	91.8	1.53	1.461	0.094	0.645	3.73
(c/d)*100(%)		13.5	17.8	21.5	28.8	18
Aging (e)	14.2	1.388	1.506	0.098	0.659	3.65
Non-aging (f)	85.8	1.427	1.339	0.087	0.599	3.451
(e/f)*100(%)		97.3	112.5	113.5	109.9	105.8
Private Consumption Expenditure in 2000	100.0	1.421	1.362	0.088	0.607	3.479

4.1.1. Air pollution

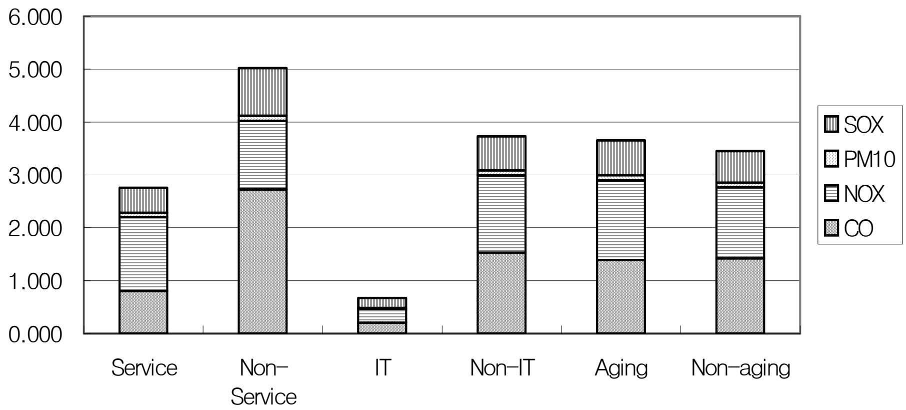
Air pollution emissions by consumption patterns were measured for 2000. Table 1 shows the estimated air pollution material emission inducement coefficients by consumption patterns derived from the air pollution vectors.

The total tonnage of air pollution material emissions per billion *won* consumption expenditure in the service sector was estimated to be 2.753, while that of the non-service sector was 5.019. Since the former turned out to be nearly half (54.9%) of the latter it is expected that a decreasing trend of air pollution per unit consumption as far as the service sector consumption share increases.

To compare coefficients by air pollution materials the service sector coefficients turned out to be as low as 0.807 and 0.472, which were equivalent to only 29.6% and 52.7% of the non-service sector coefficients in cases of CO and SO_X.

Figure 1 Comparison of Air Pollution Material Emission Inducement Coefficients by Consumption Patterns

(unit: ton, billion won)



The service sector was estimated to produce slightly more NO_X (107.3%) than the non-service sector. In the case of $PM10$ the service sector coefficient was lower (80%) than the non-service sector. The phenomenon was observed because NO_X and $PM10$ were produced mostly in transportation sectors (one of the leading service sectors).

The discrepancy between IT and non-IT sector pollution coefficients is larger. The IT sector recorded 0.672, while the non-IT sector produced 3.73 tons per billion won consumption. The former took up less than 20% (18%) of the latter. The more the IT sector consumption increases, the less air pollution is expected to be generated. The peculiarity of the IT sector consumption is that the induced air pollution material coefficients are markedly lower than those of non-IT sectors. The ratio exists of the former to the latter ranges between 13.5 and 28.8%. The indication is that all air pollution materials induced by unit consumption are expected to decrease evenly as the share of the IT sector consumptions increase.

Induced air pollution material coefficients were slightly higher than those of the non-aging group are found in the case of the aging population consumption.

Table 2 Water Contamination Material Discharge Inducement Coefficients

(unit: thousand m^3 or ton per billion won)

Consumption Patterns	Shares in 2000 (%)	Water Wastes Inducement Coefficients	BOD Load of Discharge Inducement Coefficients
Service (a)	68.0	0.4674	0.0077
Non-Service (b)	32.0	1.9344	0.0362
(a/b)*100(%)		24.2	21.1
IT (c)	8.2	0.8016	0.0148
Non-IT (d)	91.8	0.9496	0.0170
(c/d)*100(%)		84.4	86.9
Aging (e)	14.2	0.9622	0.0174
Non-aging (f)	85.8	0.9334	0.0167
(e/f)*100(%)		103.1	104.3
Private Consumption Expenditure in 2000	100.0	0.9375	0.0168

The *CO* inducement coefficient of the aging group was found to be lower, but insignificantly so (97.4%). Such an air pollution prone tendency of the aging group consumption is observed because of the lower propensity to consume IT sector goods.

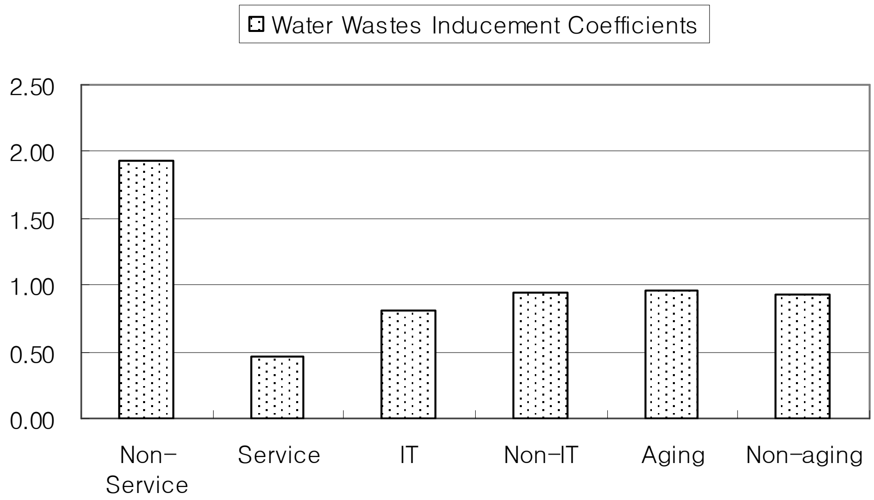
4.1.2. Water contamination

A similar procedure was taken to measure water contamination coefficients induced by consumption patterns. The compilation results are presented in table 2 and described in the form of a bar chart in figure 2.

Water pollution discharges by consumption patterns were measured for 2000. The total tonnage (thousand m^3 or ton) of water waste or BOD load of discharges per billion won consumption expenditure in the service sector was estimated to be 0.4674 and 0.0077, while that of the non-service sector was 1.9344 and 0.0362. The former estimations turned out to be lower than

Figure 2 Comparison of Water Contamination Material Discharge Inducement Coefficients

(unit: thousand m^3 or ton per billion won)



a quarter of the latter estimations (24.2% and 21.1% respectively). These results imply that much less water contamination is expected if the share of the service sector consumption keeps on increasing, it is noted that the above results were derived utilizing only industrial water waste data.

The discrepancy was much smaller than the case of the service and non-service sector comparison the water contamination inducement coefficients of the former that were found to be smaller than those of the latter (84.4% and 86.9% respectively) in the case of the IT and non-IT sector consumption comparison. Less water waste per unit consumption is expected to be generated as the share of the IT sector consumption increases.

The consumption of the aging group will produce more water waste than of the non-aging group. The water waste and BOD discharge coefficients were found to be 0.9622 and 0.0714 respectively, which were 3.1% and 4.3% higher than those of the non-aging group consumption. This tendency was observed because of the lower share of IT sector (a lower pollution generating sector) consumption, and partly because of the higher share of the health service sector (a relatively higher pollution generating sector than education service sector) consumption.

4.2. Impacts of Consumption Pattern Changes on Environmental Pollution: Simulation

Two different period observations are required to perform a factor decomposition analysis. The inability to compile environmental pollution vectors of 107 sectors only for 2000 led to a simulation study to analyze the probable impacts of consumption pattern changes on environmental pollution.

Two scenarios were established for this purpose based on 1990-1995-2000 I/O tables for the service vs. non-service, and the IT vs. non IT comparison.

Scenario Ⅰ: Same rate of change in consumption pattern shares between 1990 and 2000 will be realized between 2000 and 2010.

ScenarioⅡ: Same rate of change in consumption pattern shares between 1995 and 2000 will be realized between 2000 and 2005 and between 2005 and 2010.

In the case of aging, however, the consumption share of the aging group is projected based on the estimated growth rate of the aging group.

4.2.1. Air pollution

When service sector consumption share increases as in scenario Ⅰ, air pollution material emission coefficients of the private consumption are expected to decrease by 5.8%, from 3.479 in 2000 to 3.277 in 2010. Similarly, coefficients for CO and SO_X are assumed to decrease from 1.421 and 0.607 to 1.251 and 0.570, which are equivalent to 12.0% and 6.2% decrease respectively. In another situation, coefficients for $PM10$ are presumed to decrease slightly from 0.088 to 0.087, recording 2.1% decrease, while those for NO_X are expected to increase slightly from 1.362 to 1.371, realizing a 0.6% increase.

Table 3 Impacts of Consumption Pattern Changes on Air Pollution Emission Inducement Coefficients' Changes by Consumption Patterns: Scenario Ⅰ

(unit: ton, billion won)

	CO	NO_X	$PM10$	SO_X	Total Emissions
Private Consumption Expenditure(PEC) in 2000 (a)	1.421	1.362	0.088	0.607	3.479
PEC in 2010 (b) When Service Sector Consumption Share Increases	1.251	1.371	0.087	0.57	3.277
(b/a)*100–100 (%)	–12.0	0.6	–2.1	–6.2	–5.8
PEC in 2010 (c) When IT Sector Consumption Share Increases	1.342	1.29	0.084	0.58	3.296
(c/a)*100–100 (%)	–5.6	–5.3	–5.0	–4.5	–5.3
PEC in 2010 (d) When Aging group Consumption Share Increases	1.42	1.367	0.089	0.609	3.485
(d/a)*100–100 (%)	–0.1	0.4	0.4	0.3	0.2

When IT sector consumption share increases as in scenario Ⅰ, the private consumption is expected to accomplish a 5.3% decrease in total in air pollution emissions in tons per unit consumption with a 4.3-5.6% decrease respectively depending on air pollution materials.

When aging group consumption share increases as in the scenario, the private consumption is expected to record a 0.2% increase in total (in air pollution emissions in tons per unit consumption). NO_X and SO_X coefficients will record a 0.4% and 0.3% increase, while CO coefficients will decrease by 0.1%.

It is then possible to tabulate the simulation results as table 4 when scenario Ⅱ is applied.

Table 4 Impacts of Consumption Pattern Changes on Air Pollution Emission Inducement Coefficients' Changes by Consumption Patterns: Scenario Ⅱ

(unit: ton / billion won)

	CO	NO_X	$PM10$	SO_X	Total Emissions
Private Consumption Expenditure(PEC) in 2000 (a)	1.421	1.362	0.088	0.607	3.479
PEC in 2010 (b) When Service Sector Consumption Share Increases	1.122	1.377	0.085	0.541	3.126
(b/a)*100–100 (%)	–21	1.1	–3.6	–10.9	–10.2
PEC in 2010 (c) When IT Sector Consumption Share Increases	1.31	1.261	0.082	0.569	3.222
(c/a)*100–100 (%)	–7.8	–7.4	–7.1	–6.4	–7.4
PEC in 2010 (d) When Aging group Consumption Share Increases	1.42	1.367	0.089	0.609	3.485
(d/a)*100–100 (%)	–0.1	0.4	0.4	0.3	0.2

Results show that air pollution material emission coefficients will decrease more sharply when scenario Ⅱ is applied rather than scenario Ⅰ.[6)]

The increasing share of the service sector consumption is expected to decrease air pollution material emissions per unit consumption, mostly in CO and SO_X, while that of the IT sector consumption will decrease all air pollution material emissions evenly. On the other hand, the increasing share of the service sector and IT sector consumption is expected to generate a similar rate of decrease in air pollution coefficients in scenario Ⅰ, while that of the service sector is expected to realize a higher rate of decrease in air pollution coefficients than that of the IT sector in scenario Ⅱ. In the case of increasing share of consumption by the aging group the change will generate a slight increase in air pollution emissions.

6) Since the same scenario is applied in the case of aging, no comparison is made.

Table 5 Impacts of Consumption Pattern Changes on Water Contamination Discharge Coefficients: Scenario

(unit: thousand m^3 or ton per billion won)

	Water Contamination Discharge Coefficients	BOD Emission Inducement Coefficients
Private Consumption Expenditure(PEC) in 2000 (a)	0.93747	0.01681
PEC in 2010 (b) When Service Sector Consumption Share Increases	0.8069	0.01427
(b/a)*100–100 (%)	–13.9	–15.1
PEC in 2010 (c) When IT Sector Consumption Share Increases	0.92859	0.01668
(c/a)*100–100 (%)	–0.9	–0.8
PEC in 2010 (d) When Aging group Consumption Share Increases	0.93836	0.01683
(d/a)*100–100 (%)	0.1	0.1

4.2.2. Water contamination

The same two scenarios were applied in order to analyze the impacts of consumption pattern changes on water contamination. The results are presented in table 5 and table 6 depending on the scenario.

Both water wastes and BOD emission inducement coefficients are expected to decrease as shares of the service and IT sector consumption increase, but more sharply for the increase of the service sector consumption share than the increase in the IT sector consumption share. It is highly probable for such results to come from the fact that only industrial water wastes are considered.

Scenario Ⅱ is expected to generate a larger decrease in water wastes than scenario Ⅰ, while an increasing share of the aging group's consumption will induce an insignificant increase in water wastes.

Table 6 Impacts of Consumption Pattern Changes on Water Contamination Discharge Coefficients: Scenario Ⅱ

(unit: thousand m^3 or ton per billion won)

	Water Contamination Discharge Coefficients	BOD Emission Inducement Coefficients
Private Consumption Expenditure(PEC) in 2000 (a)	0.93747	0.01681
PEC in 2010 (b) When Service Sector Consumption Share Increases	0.70861	0.01235
(b/a)*100–100 (%)	–24.4	–26.5
PEC in 2010 (c) When IT Sector Consumption Share Increases	0.92504	0.01663
(c/a)*100–100 (%)	–1.3	–1.1
PEC in 2010 (d) When Aging group Consumption Share Increases	0.93836	0.01683
(d/a)*100–100 (%)	0.1	0.1

5. SUMMARY AND CONCLUSIONS

Environmental pollution is generated either through the production process or through the consumption process of goods and services. There is a need to concentrate on the impacts of consumption activities on environmental pollution rather than those of production activities since production is induced mainly by consumption and few studies have examined this so far.

This paper focused on the impacts of consumption pattern changes on environmental pollution in Korea. In order to accomplish this objective, this paper employed a newly-developed estimation procedure and a newly-compiled environmental data base. On the basis of such establishments, both an air and a water pollution material discharge matrix were compiled for the 105 sectors. In the case of air pollution, four major substances such as CO, NO_X, SO_X, and $PM10$ were investigated, while in the case of water pollution, both water wastes and a BOD load of discharge were considered. In addition, two scenarios were utilized for simulation in order to analyze the impacts of consumption pattern changes on environmental pollution. The final results can be summarized as follows.

First, in the case of air pollution, the increasing share of the service sector consumption is analyzed to decrease air pollution material emissions per unit consumption, mostly in CO and SO_X. Second, the increasing share of the IT sector consumption will decrease all air pollution material emissions evenly. Third, the increasing share of the service sector consumption is expected to create higher rate of decrease in air pollution material emissions such as CO and SO_X in particular, while the increasing share of the IT sector consumption is expected to create decrease in most air pollution material emissions evenly. Fourth, the increasing share of the aging population consumption will generate slight increase in air pollution material emissions. Fifth, in the case of water contamination, both water wastes and BOD emission inducement coefficients were expected to decrease as shares of the service and IT sector consumption increase, but more rapidly for the increase of the service sector consumption share than for the increase of the IT sector consumption share. In another situation the increasing share of consumption by the aging population was found to induce a slight increase in water wastes.

In sum, it is concluded that the change in consumption patterns such as the increasing shares of consumption by the service and IT sector are expected to decrease both air and water pollution material discharges per unit consumption while the growing trend of consumption by the aging population is likely to generate little change both in air and water pollution emissions.

APPENDIX

Table A1 Major Air Pollution Emissions

(unit: tons per year)

	Total Emissions	*CO*	NO_X	SO_X	*PM*10
1990	3,151,769	1,633,234	638,148	828,264	52,123
1991	3,198,842	1,560,439	695,621	887,491	55,291
1992	3,207,656	1,510,245	761,178	878,997	57,236
1993	3,235,612	1,479,407	819,171	875,888	61,146
1994	2,977,672	1,158,385	897,070	857,709	64,508
1995	2,882,578	1,091,932	888,869	837,269	64,508
1996	2,864,446	1,042,903	942,432	812,772	66,339
1997	2,795,368	1,023,814	985,843	716,284	69,427
1998	2,514,630	979,238	905,792	564,867	64,733
1999	2,395,313	805,666	974,760	545,729	69,158
2000	2,427,725	825,193	1,003,958	531,059	67,515
2001	2,510,619	837,568	1,050,997	552,173	69,881
2002	2,537,496	860,584	1,106,269	501,753	68,890
2003	2,594,411	857,952	1,167,329	499,010	70,120

Source: Ministry of Environment.

Table A2 Water Waste Fluid Before and After Treatment

(unit: thousands m^3 per day)

	Number of Enterprises	Before Treatment	After Treatment
1990	13,504	4,106	1,700
1991	14,715	5,656	1,846
1992	16,834	6,391	2,008
1993	20,241	6,412	2,093
1994	26,702	7,259	2,316
1995	25,299	8,741	2,375
1996	28,012	8,926	2,511
1997	39,939	7,469	2,618
1998	37,621	6,753	2,614
2001	48,876	7,906	2,555
2002	51,469	7,966	2,442
2003	53,851	7,971	2,363
2004	55,405	7,990	2,350

Source: Ministry of Environment.

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