地域硏究, 第8卷 第2號
1992年 12月 pp.77~88

Analysis of Effects of Pollution Tax on Regional Development: A Static Integrated Economic-Environmental Model for Seoul Region

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1. Introduction

This paper examines an inter-relationship of optimal pollution tax rate with social welfare and regional economic growth, using a multisectoral general equilibrium model for Seoul region. In this study, damage costs on environmental qualities which residents of Seoul region has paid are designed to be partially internalized by imposing the pollution tax on production costs of the industrial sector. Although a lot of studies have focused on carbon emission for the protection of global environment, this paper is concerned with SOx emission due to limitations on data availability. In order to explore the optimal pollution tax rate under specific constraints on economic activities of Seoul region, we have developed an Integrated Economic-Environmental Model composed of a regional Computable General Equilibrium (CGE) Model and a pollution-generation model for Seoul region. Seoul region is defined as Seoul city and its surrounding province, Kyunggi.

The structure of the paper is as follows. Section 2 reviews briefly the Integrated Economic-Environmental Model with providing Social Accounting Matrix (SAM) of Seoul region in 1985 as a bench mark data set. Section 3 examines the optimal pollution tax rate resulting from the utility maximization and discusses the structural adjustment in Seoul regional economy. The final section summarizes the results and present some conclusion.

2. An Integrated Economic-Environmental Model

The integrated Economic-Environmental model focuses on the analysis of Seoul regional economic and environmental activities through the integration of their interdependences and causal feedback effects in the market structure. This model can allow us to understand how the taxation and the quantity control on the emission of pollutants can affect the regional economic development. Real economic part of the Integrated Economic-Environmental Model for Seoul region is based on the interregional CGE model developed by Kim (Kim, 1992). The interregional CGE model has been designed to quantify the economic impacts of external shocks on such regional macroeconomic variables as employment, income, consumption, population, and production. One of the main advantages in the CGE approach is to propose regional development policies in a normative way by incorporating optimal behavior of economic agents such as profit and private utility maximizations of each producer and consumer. The structure of the integrated Economic-Environmental model is disaggregated into two modules: the environmental module and the regional economic module including the supply, the price, and the demand and market equilibria.

1) Regional Economic Module

In the regional economic module, there are 12 industrial sectors: 1) agriculture, fishery, and forestry, 2) mining, 3) food, 4) textile, 5) wood, 6) paper and printing, 7) chemicals, 8) nonmetals, 9) primary metals, 10) machinery, 11) other manufacturing, and 12) tertiary sectors.[1] Each industrial sector is assumed to produce a single commodity under constant returns to scale, and the product is determined by a Cobb-Douglas aggregate of the capital and the labor inputs. In a static analysis, the labor inputs are movable across sectors and fully employed with the sectoral amount of capital stock fixed exogeously. Consequently, the optimal labor demands can result from the constrainted profit maximization of producers.

Regional demands for goods are partitioned into demands for foreign imports and commodities produced in domestic regions. The latter are again disaggregated into demands for Seoul regional and other regional products. There are two stages in demanding goods in which Armington spirit with a "small country assumption" is specified. In the first stage, sectoral imports and domestic goods are imperfect substitutes, while in the second stage, regional imports and intraregionally produced goods are also imperfect substitutes due to an aggregation problem of sectoral classification and an imperfect competition of the commodity market. With a set of nested CES functions, optimal demands for three different goods are achieved from the minimization of costs subject to total demands for intermediate and final uses.

On the other hand, Seoul regional products are differentiated with exports to foreign countries, exports to other domestic regions, and supplies to Seoul region. The process to distribute their products to three regional markets is also divided into two stages: first, their total products are sold to domestic markets and foreign markets; and second, the products to be sold to domestic markets are disaggregated into supplies to Seoul and other regional markets. The optimal assignments of product supplies to three different markets are determined by constant elasticity of transformation (CET) functions of the relative differentials of domestic and export prices for the first stage, and of Seoul and other regional product prices for the second stage. Table 1 is a mathematical specification of supply block.

Mechanism in which changes in the relative price have effects on the economic behavior is one of the primary features in the model. The model has basically five different prices; composite good price, product price, value added price, import price, and export price. The domestic price of imports is determined by the nominal foreign exchange rate, the tariff rate, and the world price of imports, while the domestic price of exports is affected by the world price of exports and the export subsidy rates. The composite good price is a weighted

Table 1. Supply Block[2)]

```
1-1. sectoral output
  X(I) = as(I) * (L(I)**aph(I)) * (KK(I)**(1-aph(I))
1-2. labor demand
  WA * wdist(I) * L(I) = X(I) * PVA(I) * sha(I)
1-3. CET export aggregation function
  X(I) = at(I) * (gamma(I) * EX(I)**rhot(I) + (1-gamma(I)) * XS(I)**rhot(I))**(1/rhot(I))
1-4. Armington function for total demand
  Q(I) = ac(I) * (delta(I) * IM(I)**(-rhoc(I)) + (1-delta(I)) * XD(I)**(-rhoc(I)))**(-1/rhoc(I))
1-5. Export function
  EX(I)/XS(I) = (PE(I)/PS(I) * (1-gamma(I))/gamma(I))**(1/(rhot(I)-1))
1-6. Import function
  IM(I)/XD(I) = (PD(I)/PM(I) * delta(I)/(1-delta(I)))**(1/(1+rhoc(I)))
1-7. CET regional export aggregation function
  XS(I) = at1(I) * (gamma1(I) * REX(I)**rhot1(I) + (1-gamma1(I) ) * XSD(I)**rhot1(I))**
          (1/rhot1(I))
1-8. Armington function for domestic demand
  XD(I) = ac1(I) * (delta1(I) * RIM(I)**(-rhoc1(I)) + (1-delta1(I)) * XSD(I)**(-rhoc1(I)))**
          (-1/rhoc1(I))
1-9. Regional export function
  REX(I)/XSD(I) = (PE1(I)/PSD(I) * (1-gamma1(I))/gamma1(I))**(1/(rhot1(I)-1))
1-10. Regional import function
  RIM(I)/XSD(I) = (PSD(I)/PM1(I) * delta1(I)/(1-delta1(I)))**(1/(1+rhoc1(I)))
1-11. Regional population
  POP = LPOP * gpop
```

parameters

delta(I)	Armington function share parameter	(nation)
ac(I)	Armington function shift parameter	(nation)
rhoc(I)	Armington function exponent	(nation)
as(I)	production function shift parameter	
sha(I)	production function share parameter	
ela(I)	production function exponent	
rhot(I)	CET function exponent	(nation)
at(I)	CET function shift parameter	(nation)
gamma(I)	CET function share parameter	(nation)
delta1(I)	Armington function share parameter	(region)
ac1(I)	Armington function shift parameter	(region)
rhoc1(I)	Armington function exponent	(region)
rhot1(I)	CET function exponent	(region)
at1(I)	CET function shift parameter	(region)
gamma1(I)	CET function share parameter	(region)
lspop	labor supply / population	
gpop	natural population growth	
wdist(I	wage adjustment factor	

endogeous variables

Q(I)	composite goods supply
X(I)	domestic output by sector
XS(I)	supplies of regional products to domestic market
XD(I)	demands for domestic goods
XSD(I)	supplies of regional products to Seoul regional market
EX(I)	foreign exports by sector
IM(I)	foreign imports by sector
REX(I)	regional exports by sector
RIM(I)	regional imports by sector
WA	average wage rate
LS	labor supply
L(I)	employment by sector

exogenous variables

LPOP	population in the last period
KK(I)	capital stock

average of the price of goods produced in domestic regions and the domestic price of imports. The product price is the sum of total value of domestic sales and the value of exports divided by total outputs. The value added price is the difference between the product price and total intermediate costs. Within a given period, a set of prices are determined to equate supplies and demands of factor inputs and commodities for all corresponding markets. Table 2 is a mathematical specification of price block.

Seoul regional households can choose bewteen 12 consumer goods. They obtain their incomes from the returns of the primary inputs, and spend on the purchase of goods and services, or save after paying taxes. We do not take into account any government subsidies to households, interregional, or international transfer incomes of households. Household savings are captured with an average propensity to save which is projected from the Social Accounting Matrix of Seoul region to be discussed later. The constrainted maximization of Cobb-Douglas utility function subject to the household budget results in the demand function for each commodity which is a simple Linear Expenditure System (LES).

In the consolidated capital account, total private savings are the sum of household savings, savings from foreign countries and other domestic regions, and firms' savings to compensate for the depreciation of capital uses. Sectoral private investments by origin are calibrated from an investment origin-destination matrix, rental costs of capital, and sectoral investments by destination.

The components of government revenues are the foreign borrowings and taxes on the regional production sectors (indirect taxes), the regional households (direct taxes), the importing goods (tariff), and the generated amount of SOx (pollution tax). The indirect tax, the direct tax, and the tariff tax rates are modelled as ad valorem rates while the pollution tax rate as an excise tax. The variation in the tax rates affects the economic behavior of the household and the producer via the changes in the relative prices and the real purchasing power. The government expenditures contain government consumptions, investments, export subsidies, and expenditure on cleaning activities.

On the goods market, commodity market equilibrium can be accomplished when the sectoral demands are equal to the sum of the intermediate demands, the current consumptions, and the investments of private and government. The neoclassical closure rule is adopted in the study; the full employment with the constant real wage in the labor market side, and the nominal investment to be determined endogenously by the sum of various saving in the capital market side. The nominal foreign exchange rate is set to one as a numeraire. Table 3 is a mathematical specification of demand and market equilibria block.

2) Environmental Module

The pollution has been treated as a non-monetary byproduct creating negative externalities. The main idea on the environmental module of the model are as follows.

1) The primary instrument of the government to reduce the emission level is the pollution tax on SOx.

2) The amount of SOx created in the production process would be removed by the only cleaning activity of the government since the pollution is

Table 2. Price Block

2-1. Import price
PM(I) = PWM(I) * ER * (1 + tm(I))
2-2. Export price
PE(I) = PWE(I) * (1 + te(I)) * ER
2-3. Composite good price
P(I) * Q(I) = PD(I) * XD(I) + PM(I) * IM(I)
2-4. Output price
PX(I) * X(I) = PS(I) * XS(I) + PE(I) * EX(I)
2-5. Value added price
PX(I) * (1-itax(I)) = PVA(I) + TENP * enp(I) + Σio(J, I) * P(J)
2-6. Price of Capital good
PK(I) = ΣP(J) * imat(J, I)
2-7. General price index
PINDEX = ΣΣpwt(I) * P(I)
2-8. Price of importing good produced in other regions
PD(I) * XD(I) = PSD(I) * XSD(I) + PM1(I) * RIM(I)
2-9. Price of exporting good to other regions
PS(I) * XS(I) = PSD(I) * XSD(I) + PE1(I) * REX(I)

parameters

io(I, J)	input-output coefficient
te(I)	export subsidy rates
tm(I)	tariff rates on imports
pwt(I)	CPI weights
enp(I)	sectoral pollutant coefficient

endogenous variables

PD(I)	domestic goods price (demand side)
PS(I)	domestic goods price (supply side)
PSD(I)	price of regional goods in local market
PM(I)	domestic price of imports
PE(I)	domestic price of exports
PK(I)	rate of capital rent
PX(I)	product price
P(I)	composite goods price
PVA(I)	value added price
PE1(I)	price of regional exports
PINDEX	Consumer Price Index

exogenous variables

ER	foreign exchange rate (Won per Dollar)
PM1(I)	price of regional imports
PWM(I)	world market price of imports
PWE(I)	world market price of exports
TENP	pollution tax rate

thought to be a bad public good.

3) The private sector would not involve in the cleaning activity.

4) All cleaning costs are financed by the pollution taxes which is an earmarked tax.

5) The revenues raised by the pollution tax depend on the pollution

Table 3. Demand and Market Equilibria Block

3-1. Household consumption
$P(I) * CD(I) = \Sigma cles(I) * YD$
3-2. Household disposable income
$YD = YH * (1\text{-}htax) * (1\text{-}mps)$
3-3. Household labor income
$YLC = \Sigma WA(I) * L(I) * wdist(I)$
3-4. Household capital income
$YKC = \Sigma(PVA(I) * X(I) - depr(I) * PK(I) * KK(I) - WA * wdist(I) * L(I))$
3-5. Household income
$YH = YLC + YKC$
3-6. Household savings
$HHSAV = mps * YH * (1\text{-}htax)$
3-7. Government revenues
$GR = TARIFF + INDTAX + TOTHHTAX + FBOR * ER$
3-8. Government expenditure
$GR = GDTOT + GOVSAV + NETSUB$
3-9. Tariff revenues
$TARIFF = \Sigma\Sigma tm(I) * IM(I) * PWM(I) * ER$
3-10. Indirect tax revenues
$INDTAX = \Sigma\Sigma itax(I) * PX(I) * X(I)$
3-11. Export subsidies
$NETSUB = \Sigma\Sigma te(I) * EX(I) * PWE(I) * ER$
3-12. Household direct tax revenues
$TOTHHTAX = \Sigma htax * YH$
3-13. Depreciation
$DEPRECIA = \Sigma\Sigma depr(I) * PK(I) * KK(I)$
3-14. Total savings
$SAVINGS = HHSAV + DEPRECIA + FSAV * ER$
3-15. Investments by sector of destination
$PK(I) * DK(I) = kio(I) * INVEST$
3-16. Investments by sector of origin
$ID(I) = \Sigma imat(I,J) * DK(J)$
3-17. Current balance of account (nation)
$\Sigma PWM(I) * IM(I) = \Sigma PWE(I) * EX(I) + FSAV + FBOR$
3-17. Current balance of account (region)
$\Sigma PM1(I) * RIM(I) = \Sigma PE1(I) * REX(I) + RSAV$
3-18. Goods market equilibrium
$Q(I) = INT(I) + CD(I) + ID(I) + gies(I) * GOVSAV + gles(I) * GDTOT$

parameters

gles(I)	government consumption shares	depr(I)	depreciation rates
cles(I)	private consumption shares	kio(I)	shares of investment by sector of destination
gies(I)	government investment shares		
imat(I, J)	private investment matrix	itax(I)	indirect tax rates
mps	marginal propensity to save	htax	income tax rates

endogenous variables

INT(I)	intermediate demands	DEPRECIA	depreciation aexpenditures
CD(I)	final demands for private consumption	INVEST	total investments
ID(I)	final demands for investments	SAVINGS	total savings
YLC	labor income accruing to labor input	DK(I)	investment by sector of destination
YKC	capital income accruing to capital input		
GR	government revenue	YH	household income
TARIFF	tariff revenue	YD	housejold disposable income
INDTAX	indirect tax revenue	TOTHHTAX	household tax revenue
NETSUB	export subsidies	FSAV	net foreign savings
HHSAV	household savings	RSAV	net investments on other regions

exogenous variables

GDTOT	total volume of government consumption
FBOR	net foreign borrowings
GOVSAV	government investments

tax rate, the generated amounts of SOx, the output level, and the pollution coefficient representing the ratio of the amount of SOx to unit product.

5) The sectoral pollution coefficient is fixed.

6) The pollutant is not a stock but a flow.

7) The cleaning industry does not demand any primary inputs, so an increase in the public expenditures on the cleaning activity cannot have any direct impacts on Seoul regional income.

The social welfare is defined by a Stone-Geary utility function and the weight value for the cleaning activity of the function is assumed to be 0.2. Economic penalties such as the taxation and the effluence charge imposed on the amount of emission are designed to decrease the pollution level and attain the internalization of social external costs in the industrial sector. The private utility increases only with the commodity consumption, while the social welfare is indifferent between the commodity consumption of the household and the cleaning activity of the government. By incorporating the pollution tax in the product price, a rise in the tax rate leads to a decline in the regional income and the private utility, with an increase in the product price. Its impacts on the social welfare is expected to depend on substitution effects between the private goods and the cleaning activities. Due to data limitation, we use national average of the pollution coefficient by sector reported by Rhee and Shin (1991). Table 4 is a mathemtical specification of environmental module.

The integrated Economic-Environmental model is implemented with the Social Accounting Matrix of Seoul region and supplementary time series data for sectoral economic activities (Kim, 1992). The model is bench-marked against a base year of 1985. Table 5 represents an aggregate Social Accounting Matrix without the activity of the cleaning sector. The model has as 323 independent equations as endogenous variables in the model and is solved by using a General Algebraic Modelling System (GAMS). The optimal solution for the model as a simultaneous and nonlinear problem can be attained when excess demands for commodities and abnormal profits for producers are vanished. The model is designed only for the analysis of the

Table 4. Environmental Module

4-1. Private utility

PUTILITY = ΠCD(I)**cles(I)

4-2. Social welfare

SUTILITY = (ΠCD(I)**sles(I)) * (CLEAN**ssles)

4-3. Cleaning activity

CLEAN = ΣX(I) * enp(I) * TENP

parameter

sles(I)	social welfare parameter for private commodity
ssles	social welfare parameter for cleaning activity

endogenous variables

PUTILITY	private utility
SUTILITY	social welfare
CLEAN	public expenditure to clean up pollutants

Table 5. Aggregate Social Accounting Matrix of Seoul (unit: 100 billion Won)

	factor account	household account account	produc- tion Country	Rest of the ment	private invest- ment	public invest- tion	public consump- account	govern- ment World	Rest of the	TOTAL
factor account	0	0	259.86	0	0	0	0	0	0	259.86
household account	259.86	0	0	0	0	0	0	0	0	259.86
production account	0	160.22	452.03	196.68	67.78	20.70	42.12	0	134.05	1073.57
Rest of the Country	0	0	191.69	0	4.98	0	0	0	0	196.68
private investment	0	78.17	34.07	0	0	0	0	0	12.84	125.08
public investment	0	0	0	0	0	0	0	20.70	0	20.70
public consumption	0	0	0	0	0	0	0	42.12	0	42.12
government account	0	21.47	40.22	0	0	0	0	0	7.98	69.68
Rest of the World	0	0	95.70	0	52.31	0	0	6.86	0	154.87
TOTAL	259.86	259.86	1073.57	196.68	125.08	20.70	42.12	69.68	154.87	

effects of different policy scenario and not for economic forecasting.

3. Pollution Taxation and Regional Development

This section aims at examining impacts of the pollution tax on Seoul regional development and the employment structure. In the maximization of the private utility subject to the value of the social welfare, an optimal solution for the pollution tax rate is yielded in a static approach.

1) Macro Impacts on Seoul Regional Development

We summarize briefly a comparative result of the regional economic and environmental elements by alternative level of the social welfare in Table 6. Table 6 indicates that there is a simultaneous reduction in the private utility and the regional income with the rise in the pollution tax rates and the price level, as the social welfare level increases from 23.1942 (EX1) to 28.9244 (EX6).

The creation of the pollution tax in order to internalize social costs in the industrial sectors of Seoul region is successful in bringing down the level of dirt amounts without inflating the price level considerably. For example, one unit change in the pollution tax can decrease 0.0042 unit change in the dirt amount, while it generates to increase only 0.0009 unit change in the price level. With the removal of the pollutants through revenues raised by the pollution tax, Seoul regional households are not better off in terms of the income and the private utility representing its purchasing power, but the social welfare level gets improved.

Table 6. Effects of Pollution Taxes on Regional Development

	EX1	EX2	EX3	EX4	EX5	EX6
			Exogenous Change			
Social welfare	23.1942 (100.0)	24.3471 (104.97)	25.4976 (109.93)	26.6448 (114.88)	27.7876 (119.80)	28.9244 (124.71)
			Economic Variables			
Consumer price index	1.0323 (100.0)	1.0326 (100.03)	1.033 (100.07)	1.0334 (100.11)	1.034 (100.16)	1.0347 (100.23)
Private utility	39.7755 (100.0)	39.6347 (99.65)	39.4584 (99.20)	39.2377 (98.65)	38.9602 (97.95)	38.6080 (97.06)
Regional income*	264.6954 (100.0)	263.7369 (99.64)	262.5378 (99.18)	261.0367 (98.62)	259.1498 (97.90)	256.7557 (97.00)
Wage level**	4.1846 (100.0)	4.1775 (99.83)	4.1686 (99.62)	4.1575 (99.35)	4.1435 (99.02)	4.1257 (98.59)
			Pollution Variables			
Pollution tax rate	0.0092 (100.0)	0.012 (130.43)	0.0154 (167.39)	0.0197 (214.13)	0.0252 (273.91)	0.0321 (348.91)
Expenditure on cleaning*	3.144 (100.0)	4.07 (129.45)	5.2282 (166.29)	6.6777 (212.40)	8.4991 (270.33)	10.8091 (343.80)
Level of dirt amount	339.9283 (100.0)	339.5028 (99.87)	338.9688 (99.72)	338.2979 (99.52)	337.4505 (99.27)	336.3688 (98.95)

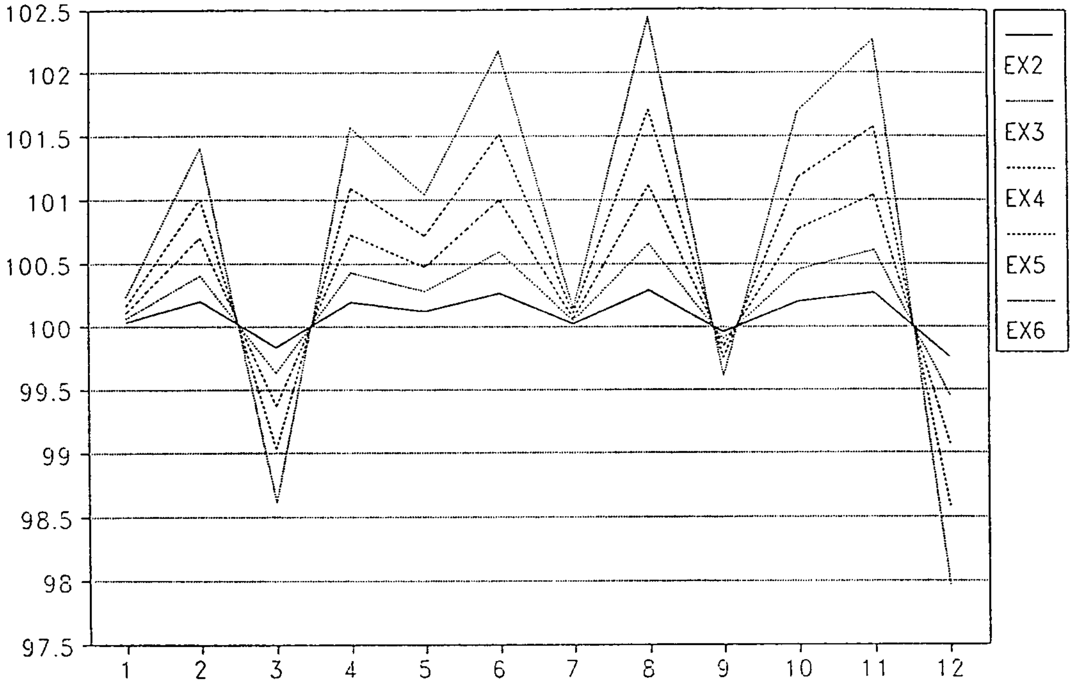
note:
1) The value in the parenthesis is a relative number with respect to EX1.
2) EX1:The level of social welfare is set to 23.1942.
EX2:The level of social welfare is set to 5% increase of level of EX1.
EX3:The level of social welfare is set to 10% increase of level of EX1.
EX4:The level of social welfare is set to 15% increase of level of EX1.
EX5:The level of social welfare is set to 20% increase of level of EX1.
EX6:The level of social welfare is set to 25% increase of level of EX1.
3) unit: * 100 billion Won, ** million Won

On the other hand, the effect of the pollution tax on the wage level is lower than on the income; the pollution tax elasticity of the wage level is -0.00565, while that of the income is -0.01205. It implies that capital-owners lose more money than wage earners by the establishment of the pollution tax. On the whole, the pollution tax point-elasticities of economic and environmental variables get more magnified as the pollution tax rate increases from 0.0092 (EX1) to 0.0321 (EX6).

2) Sectoral Impacts on Seoul Regional Employment

Figure 1 presents relative changes in sectoral employments with the rise of the pollution tax rate. There is a decline in the sectoral employments of the food, the primary metals, and the tertiary sectors, while a slight increase in the paper and printing, the nonmetals, and the other manufacturing sectors.

Because the assumption of the full employment in the labor market is employed in the model, some sectors could induce more labor demands in



* The employment by sector of EX1 is set to 100.
(1) agriculture, fishery, and forestry, (2) mining, (3) food, (4) textile, (5) wood, (6) paper and printing, (7) chemicals, (8) nonmetals, (9) primary metals, (10) machinery, (11) other manufacturing, (12) tertiary sector

Figure 1. Sectoral Employment by the Pollution Tax Rates

spite of the increase of their production costs and the reduction of the value added prices. If the full employment condition is abandoned in the labor market closure rule, the introduction of the pollution tax in the economic system could drive the level of employers in all sectors to go down. This structural adjustment in the labor demand can be reviewed with regard to the environmental and economic aspects.

Table 7 presents the sectoral pollution coefficient which is the amount of the generated SOx per monetary unit. This has been transformed to non-monetary term with setting the product price to 1.00 in the bench mark data in the model.

Table 7. Pollution Coefficient by Sector
(unit: kg / million Won)

sector	coefficient	sector	coefficient
1	9.624576	7	12.233740
2	6.265074	8	0.977345
3	4.135903	9	23.486000
4	4.109355	10	4.525570
5	N.A.*	11	0.453978
6	6.095411	12	79.183540

(1) agriculture, fishery, and forestry, (2) mining, (3) food, (4) textile, (5) wood, (6) paper and printing, (7) chemicals, (8) nonmetals, (9) primary metals, (10) machinery, (11) other manufacturing, (12) tertiary sector
source: Rhee and Shin (1991)
*: The value is assumed to be zero.

Ceteris paribus, the pollution tax can have more dampening effects on the growth of the tertiary and the primary metals sectors because of their comparatively high pollution coefficients. However, Table 7 fails to analyze a relative reduction in the labor demand of the food industry because the pollution coefficient is low. Consequently, we need to investigate other economic factors to explain the variation in the employment level which is determined by the wage adjustment factor, the Seoul regional wage rate, and the value added price in the model system. The wage adjustment factor cannot be changed in the short run due to its institutional property and the same level of regional wage rate is applied to all industrial sectors, therefore the relative differential in the value added price by sector is the major element to affect the labor mobilities between sectors in the static analysis.

The ratio of the value added price to the product price is outlined in Table 8. Table indicates that the value added prices in the food (0.1400), the primary metals (0.1775), the wood (0.2182), and the textile (0.2361) sectors are more sensitive to the change of the intermediate costs, while the mining (0.7478), the agriculture, fishery, and forestry (0.7230), and the tertiary (0.4872) sectors are less. As a result, if there is an increase of the product prices caused by imposing the pollution tax, it yields inevitably a remarkable drop in the value added price of the food industry. It explains partially the reduction in the labor demand of the food sector and it implies that the food sector would experience a negative growth in spite of less pollution industry.

Table 8. Ratio of the Value Added Price to the Product Price by Sector

sector	Value Added Ratio	sector	Value Added Ratio
1	0.7230	7	0.2613
2	0.7478	8	0.3294
3	0.1400	9	0.1775
4	0.2361	10	0.2860
5	0.2182	11	0.2769
6	0.2959	12	0.4872

(1) agriculture, fishery, and forestry, (2) mining, (3) food, (4) textile, (5) wood, (6) paper and printing, (7) chemicals, (8) nonmetals, (9) primary metals, (10) machinery, (11) other manufacturing, (12) tertiary sector

4. Conclusion and Limitations

The paper has presented an Integrated Economic-Environmental model to quantify the economic impacts under specific social goals through incorporating rational behavior on the economic side. The primary feature of the model is to review alternative adjustment programs of environmental policies in terms of regional economies. This study finds that the taxation on the pollution is revealed to be successful in the improvement of the environmental quality and the social welfare, but it would cause the regional incomes and the private utility to reduce. The taxation on the SOx emission generates the structural change in the employment pattern; decreases of sectoral labor demands in the food, the primary metals, and the tertiary sectors. This variation in the employment structure can be explained by sectoral relative differences in the pollution-generation and the sensitivity of the value added price to changes in other product prices. The government policy to impose the pollution tax on industries has positive effects on the reduction of pollutants, but it results in an undesirable side-effect, a negative growth of the food industry although the sector produces relatively less pollutants in the production system.

Note

1) This sector include construction, utility, trade, transportation, communication, financing and insurance, and social services.
2) The Capital "I" refers to industrial sector: (1) agriculture, fishery, and forestry, (2) mining, (3) food, (4) textile, (5) wood, (6) paper and printing, (7) chemicals, (8) nonmetals, (9) primary metals, (10) machinery, (11) other manufacturing, (12) tertiary sector

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