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Environmental Regulation, Process Innovation and Social Cohesion in Korea

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Abstract

Combining input-output analysis and the growth-accounting formula of total factor productivity, this paper unveils the links between environmental regulation, process innovation, and social cohesion in Korea. Focusing on interactions between CO_2 emissions regulation and inter-industrial performance, this paper first explores the spillover role of the process innovation of major manufacturing sectors in overall price competitiveness in Korea. Then, it simulates the countervailing economic spillover effects of process innovation on income inequality in the face of CO_2 emissions regulation and provides policy recommendations for Korea.

Keywords: Carbon Regulation, Income Inequality, Manufacturing Industries, Price Competitiveness, Process Innovation, Technological Spillovers

1. Introduction

Recently, the Korean government and individual firms have become very concerned about how to respond to global carbon regulation[2]. Korea's climate change policy measures mainly relate to energy conservation and energy efficiency in energy-intensive manufacturing industries. Improving process innovation in core manufacturing sectors could also enhance international competitiveness and promote balanced growth in an era of climate change[6]. Energy-related, process-innovative, next-generation technologies that have large economy-wide spillover effects could be developed by government-led R&D programs and investments. As for the iron and steel industry, for instance, the policy goes further; coal, containing the largest amount of carbon per unit energy content among all fossil fuels, is used as a key source of input into iron- and steel-making processes. According to input–output analysis[3], the iron and steel sector has both a high power of dispersion and a high degree of sensitivity, which implies that it has close interrelations with other industries. In this paper, as a study on links between CO_2 regulation and process innovation, we explore "what is lost or to be overcome from the regulation of carbon emission on energy use," focusing on the role of process innovations in major manufacturing industrial sectors in Korea.

2. Modeling Technological Linkages and Spillovers

The model in this study contains 32 non-energy industrial sectors and 18 energy sectors as in Table 1. of a total of 50 industries, we focused on Chemicals & Allied products (No.11), Iron & Steel products (No.14), General machinery (No.17), Electric & Electronic equipment (No.18), Transportation equipment (No.19) and Construction (No.22) as some of the major manufacturing and related industries because these industries play important roles in inter-industrial linkages and spillovers of Total Factor Productivity (TFP) for their international competitiveness in Korea.

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Table 1. Inter-industrial Model: Sector Classification

No.	Sector	No.	Sector	No.	Sector	No.	Sector	No.	Sector
	Agri. Fore. & Fish.	11	Chemicals & Allied	21	Miscel. manufac.	31	Medical & Health	41	Heavy oil
1	Non-fuel mining	12	Rubber & Plastic	22	Construction	32	Other services	42	LPG
2	Food products	13	Cements	23	Wholesale & Retail	33	Anthracite	43	Lubricants
3	Alcohol	14	Iron & Steel	24	Accom. & Dining	34	Bituminous coal	44	Other oils
4	Tobacco	15	Nonferrous metals	25	Transportation	35	Coal products	45	Steam & Hot
5	Textile	16	Fabricated metals	26	Communications	36	Naphtha	46	City gas
6	Leather	17	General machinery	27	Finance	37	Gasoline	47	Hydro-electric
7	Lumber & Wood	18	Electrical &	28	Real estate	38	Jet oil	48	Fire power
8	Papers	19	Electronic	29	Public services	39	Kerosene	49	Nuclear
9	Printing &	20	Transp. equip.	30	Education	40	Light oil	50	Other electric
10	Publishing		Precision						
			instruments						

Source: Bank of Korea, Input-Output Table, 2012.

Combining input–output analysis and the growth-accounting formula of TFP[5], price competitiveness for each industrial sector can be expressed as:

$$\frac{dPX}{PX}=\left[I-W'\hat{W}_x\right]^{-1}\left[\frac{d\tau}{\tau}+W'\left(I-\hat{W}_x\right)\frac{dPM}{PM}+\hat{W}_o\frac{dPO}{PO}+\right.$$
$$\left.+\hat{W}_L\frac{dPL}{PL}+\hat{W}_K\frac{dPK}{PK}+\frac{dTFP}{TFP}\right]$$

Here PX, τ, PO, PL, and PK denote vectors of output prices, indirect tax rates, imported oil prices, wages and rental prices, respectively. W is input–output coefficients matrix, W_O, W_L, W_K, and W_X denote a diagonal matrix of input shares of imported oil, labor, capital, and domestic products, respectively.

2.1 The Benefits of Technological Linkages and Spillover by Industry

Furthermore, Figure 1 and Figure 2 show the key spillover role of sectoral TFP in overall industrial competitiveness activities. This represents the spillover contribution effects of process innovation induced by technical progress in major manufacturing industries on overall price competitiveness in Korea. As shown by this Figure, the sectors of Iron & Steel products (No.14) and Chemicals & Allied products (No.11) have both a high power of dispersion and a high degree of sensitivity. This implies that, these industries, in inter-industrial relationships, have close interrelations with other industries where their expansion would lead to a general increase in economic activity embracing all or at least most industries.

We next consider the effects of process innovation under carbon regulation in Korean industries. Figure 3 represents the economic impacts of efficient energy management and

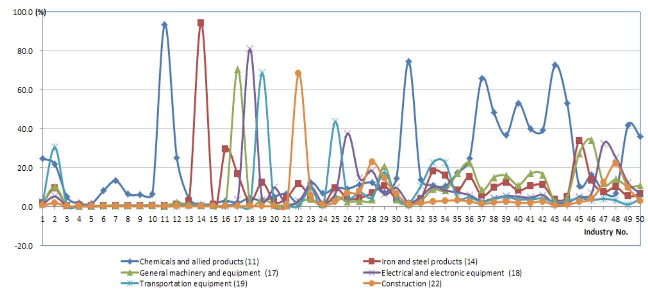


Figure 1. The industry-wise technological spillovers of sectoral TFP in Korea.

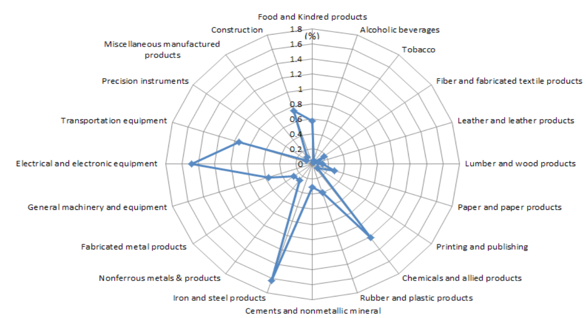


Figure 2. The role of sectoral TFP in overall industrial competitiveness in Korea.

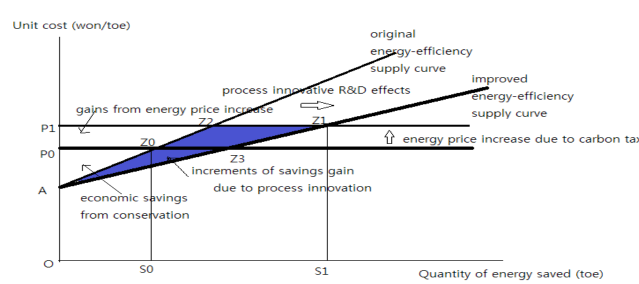


Figure 3. Economic benefits of process innovation.

conservation such as process-innovative technologies on manufacturing industry in the case of carbon taxation.

2.2 The Costs of Carbon Regulation

The total carbon emissions in Korea have increased, largely from carboniferous and hydrocarbon-containing fossil fuels. However, they are expected to increase at a lower growth rate than ever before, due in part to more efficient energy use and shifts in the output mix toward less energy- and emission-intensive products. The more efficient energy usage and lower carbon emissions have also been achieved by the expansion of the electric-arc smelter of steelworks and the introduction of continuous casting processes. In the iron and steel-making industry, for example, the largest emission reduction potential involves innovative energy-efficient processes and fuel substitution. The process innovation towards more cost-effective energy use would be crucial in overall industrial performance in the future.

The energy and environmental market is well known as the most typical example of market failure. The Korean energy market is not yet cleared at the Pareto-efficient state, owing to the presence of such externalities as an import premium on imported energy or the energy-related environmental pollution cost[1]. Thus, we need to internalize these negative externalities by taxing energy consumption.

Based on the experience of OECD countries, Korea is considering the introduction of a carbon tax to curb CO_2 emissions in the near future, which taxes the combustion of fossil fuels according to their carbon contents, while addressing properly their potential impact on international competitiveness and distributional concerns. The Korean government is considering internalizing further other environmental costs in setting tax rates on energy, phasing out various exemptions and environmentally harmful subsidies. According to the analysis of McKinsey's Antonio Volpin and Cambridge Econometrics in the UK, the average market price per ton of CO_2 emission trading is estimated as 25 euro (= 36,382 Korean won in 2009) from 2008 to 2012. Following this,[2] suggests a carbon tax scheme in Korea, as the rate of emission costs per each energy source can be measured by multiplying the price of 36,382 won and the unit amount of CO_2 emissions in Table 2 (aimed at a 30% reduction of total carbon emissions by year 2020).

As in Table 2, a carbon tax of 25 euro per ton of CO_2, raising 11.8 trillion won tax revenue (= about 1% of GDP), would allow for a smoother transition to a less carbon-intensive economy in Korea. Businesses and households would replace their equipment and energy-use practices with more efficient alternatives.

However, cutting CO_2 emissions would involve costs that would hurt international competitiveness and income distribution. Investigating the economic burden among industries that might be imposed in the proposed scenario in Korea,[2] found that the impacts on each industry vary to a great degree. According to the results, Iron & Steel, Cements & Non-metallic and Chemicals and Allied products have non-trivial economic costs in curtailing carbon emissions.

Carbon taxes might be a practical tool for domestic policy aimed at reducing carbon emissions. However, in reality the implementation of this carbon pricing is not likely to be effective until serious concerns about impacts on major industrial competiveness and income distribution are resolved. In order to protect international competitive positions, it would be desirable to consider subsidizing process innovation for major industrial sectors. Moreover, the tax credit for other R&D investments in the major manufacturing industries, made possible by carbon tax revenue, would offer an economic benefit, providing a moderate offset to the cost of carbon reduction. As far as the income regressiveness of carbon tax is concerned[7], it is also important to devise appropriate compensation fiscal schemes for the poor households group.

Table 2. Proposed Carbon Tax Schemes on Energy Consumption in Korea (25 euro per ton of CO_2)

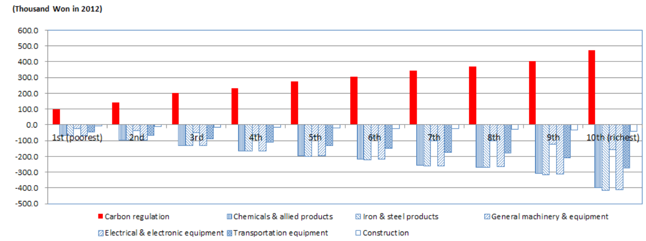
Energy sources		Gasoline (won/ℓ)	Diesel (won/ℓ)	Kerosene (won/ℓ)	B-C oil (won/ℓ)	Butane (won/ℓ)	Propane (won/kg)	LNG (won/kg)	Bituminous. Coal (won/kg)
Current tax rates (excluding VAT)		745	528	104	20	185	20	60	24
Carbon Taxation	Social Cost	67.5 (4.4%)	82.4 (6.5%)	77.7 (8.29%)	95.5 (19.4%)	53.2 (6.9%)	92.0 (6.9%)	71.0 (11.1%)	33.7 (45.6%)

Note: 1) Numbers in parenthesis represent increase in prices for each energy product by carbon taxation.
2) Scenario for carbon taxation of Social Cost is assumed to raise 11.8 trillion won of tax revenues.

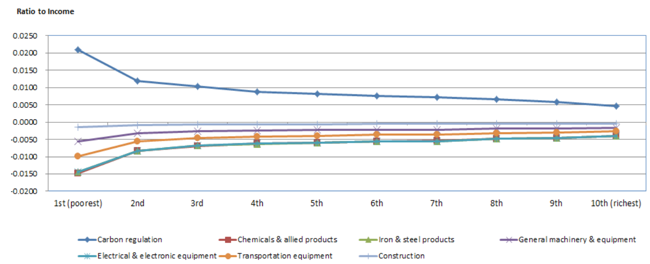
3. Equity Effects of Carbon Pricing and Process Innovation in Korea

As seen in the literature, the introduction of carbon tax would be income-regressive[2,6,7]. However, the negative distributional effects of a carbon regulation could be tremendously mitigated and even reversed by the countervailing positive effect on income distribution of process innovation policies. Using the input–output micro-simulation incidence method as in[2,4], we estimate economic burdens of these policies by income docile based on the 2012 Household Income and Expenditure Survey (HIES) data in Korea. According to our simulation results in Figure 4, the positive spillover effects on income distribution of process innovation (10% TFP increase) in each of the major industries such as Chemicals & Allied products (No.11), Iron & Steel products (No.14), General machinery (No.17), Electric & Electronic equipment (No.18), Transportation equipment (No.19), and Construction (No.22) would be significant.

This is driven by the industry-wide cost-down spillover effects of process innovation technologies in the major manufacturing industries. In particular, process innovation in Iron & Steel products (No.14) and Chemicals & Allied products (No.11) on overall economy-wide activities would be fairly significant. For instance, the hot-rolled milling process and crude steel-making process would have a large amount of effect on output inducement and on spillover cost-down in overall industrial performance in Korea.



(a) Incidence : absolute amount



(b) Incidence: ratio to income

Figure 4. (a) and (b) Effects of carbon pricing and process innovation by income decile in Korea.

From experience in countries that have already implemented ecotax reform in Europe, we may need a gradual phasing-in of carbon pricing and the earmarking of the use of the tax revenues as stronger incentives for and to encourage process innovation investments by, the major industries illustrated in Table 3.

Table 3. Efficiency and Equity Effects of Carbon Pricing and Process Innovation in Korea

	Negative effects of carbon regulation (25 EUR/ tCO_2)	Countervailing Positive Effects of Process Innovation (10% TFP increase) in:					
		Chemicals & allied products (No.11)	Iron & steel products (No.14)	General machinery (No.17)	Electrical & electronic equipment (No.18)	Transportation equipment (No.19)	Construction (No.22)
Efficiency cost (1,000 won)	+281.13	−211.90	−216.17	−83.65	−214.52	−143.64	−21.07
Equity cost (%)	+0.2726	−0.1595	−0.1520	−0.0601	−0.1509	−0.1045	−0.0157
Priority rank of process innovation	-	2	1	5	3	4	6

Note: 1) Efficiency cost is calculated as average burden across income deciles due to carbon regulation or process innovation.

2) Equity cost is measured as percentage change of Gini coefficient due to carbon regulation or process innovation. Reference Gini coefficient in the 2012 HIES data is 0.370654. The Gini coefficient (G), as inequality index, is measured as follows:

$$G = \Delta / 2\mu, \quad \Delta = 1/n(n-1)\sum_i^n \sum_j^n |y_i - y_j|$$

Where Δ = average income gap of whole population, n = population size.

Overall, with process innovation in response to carbon regulation, the negative effects of the carbon tax scheme on income distribution would be minimal in Table 3. Using the input–output micro-simulation incidence method as in[2,4], our results in Table 3 indicate that the carbon pricing policy would not be significantly regressive and could even be progressive. In this case, however, additional revenue from carbon taxation might need to be used to increase tax benefits for various corporate investment and R&D efforts towards process innovation activities. That is, the equity effects from carbon taxation would largely depend on how the carbon tax revenue is spent rather than how it is raised. In implementing the appropriate ecotax reform, it is necessary to partly weigh up conflicts among economic efficiency, social equity, and issues of administrative feasibility in the energy-intensive sectors.

4. Conclusion

The best response strategies of manufacturing industries in Korea would be to incorporate environmental considerations into all business activities and to introduce new energy-efficient technologies through process innovations, rather than undergoing non-productive end-of-pipe (or add-on-device) pollution treatment and energy substitutions into other fuels with less carbon content. The energy savings program through process innovation and efficient energy use would be superior to other programs. In this case, energy-efficiency improvement rather than fuel switching should be encouraged in the major industrial sectors. The use of more cost-effective energy technologies and processes could increase overall industrial performance and social cohesion together in Korea.

Carbon pricing might be a practical tool for ensuring energy conservation and greenhouse gas emissions reduction in Korea. However, as shown in this study, carbon pricing combined with process innovation in the major key industries would be more desirable for both economic efficiency and social equity. In this case, energy R&D investment tax credits or business tax cuts in these industries can be considered. Energy-intensive material-processing industries will need to be further reinforced by national and corporate energy-related R&D programs, often in joint ventures.

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