Induced Production and Employment Analysis of Photovoltaic Equipment Industry in Korea

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Overview

The Input-Output table contains micro information about industry's flow of production and technology. The Renewable Energy Input-Output table focuses on renewable energy flows in and out of industry. And this table contains production technology of renewable energy equipment manufacturing industry. Renewable Energy Input-Output table expands research target to indirect effect of investment in renewable energy sector and helps to evaluate relative priority among Government budget. Published Input-Output table may not need to contain renewable energy sector. Because climate change becomes a big issue, because demand of emerging country increases rapidly, and because developed countries find new growth force, renewable energy is one of the major topics nowadays. Renewable energy is considered as an option to substitute other imported energy sources and to mitigate greenhouse gas emissions in Korea. In case of Korea, energy dependency on overseas is 96.5% in 2011, and Korea is the world's 7th country in GHG emissions. But renewable energy has small share in TPES in Korea.

The Korean government introduced the *Alternative Energy Development Promotion Act* in 1987 to promote alternative energy. The *2nd Basic Plan* of 2003 aimed to raise the production share of renewable energy system in TPES to 5% by 2011 and to 9% by 2015. The *3rd Basic Plan for Development, Usage and Deployment of RE technology of 2008* revised the targets of the 2nd Basic Plan for the production share of renewable energy system to 4.3% in TPES by 2015 and 11% in TPES by 2030. Korea introduced the feed-in-tariffs (FIT) and R&D fund to accelerate deployment of renewable energy system in 2002. The amount of R&D, deployment, and FIT are 1,142 Billion Won, 1,929 Billion Won and 769 Billion Won respectively during 2003-2010. The R&D budgetary supports for renewable energy system increased by 6.8 times in this period.

Korea introduced the feed-in-tariffs (FIT) scheme to accelerate the deployment of renewable energy system in 2002. This scheme has been financed by *Electric Power Infrastructure Fund* established in 2001, which has been generated by a levy of 3.7% on electricity bills of all consumers in Korea. The Korean government has changed deployment of renewable energy system from FIT to RPS since 2012. Main reason of the shift to the renewable energy system promotion scheme was a rapidly growing amount of FIT payments. As the FIT subsidy payments are guaranteed for 20 years, the effective governmental supports or subsidies will be much bigger than annual subsidy payments. These payments will surely increase the burden on the government budget. This burden might partially cause to terminate the FIT scheme by the end of 2011 and to introduce the RPS scheme from 2012. Under the RPS scheme, 14 state-run and private power utilities with a capacity more than 500 MW are obliged to generate 4% of electricity with renewable energy system by 2015 and 10% by 2022. The Korean government hopes with this RPS scheme to increase the generation capacity with renewable energy system by 350 MW yearly until 2016 and by 700 MW yearly until 2022.

This discussion shows that impacts of investments in renewable energy system on income and employment will largely depend on the productivity of investments in renewable energy system, which can be compared with such productivity in conventional energy sources or in the rest of the economy. renewable energy system will become competitive compared to conventional energy sources if its kWh generation cost decreases to the level which is higher only by the cost of reducing CO_2 emissions. Thus, the productivity of investments in renewable energy system, in turn, will depend on the cost of investments required to meet the same demand by relying upon conventional energy sources on the one hand and the cost of reducing CO_2 emissions on the other hand. It is a question to answer what is the amount of opportunity costs of renewable energy promotion.

The question is how to evaluate a quantities effect of such deployment policy in renewable energy in Korea. Data availability for renewable energy or energy flow of industry is one of issues in empirical analysis. Only macro

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data of renewable energy is published because renewable energy has small share in TPES compared with other conventional energy sources. However, each industry has different production technology and energy input-output structure. In addition technology progress happens along the time. The Input-Output table contains RE flows, assisting to proceed comparison analysis among industries.

This paper generates methodology for Renewable Energy Input-Output table in Korea and shows segmentation of renewable energy from conventional industry. This study builds a Renewable Energy Input-Output table based on financial statements of representative company in renewable energy source, "Survey of Renewable Energy Industry", "Energy statistics", and energy sector data from "Input-Output table". Data from financial statements of representative company provides more accurate information when Renewable Energy Input-Output table is made. This study tries to assess impacts of renewable energy promotion on income and employment in Korea by using the Input-Output method.

The remainder of this paper is organized as follows: the second section discusses the renewable energy policy in Korea; the third section reviews previous researches; the fourth section discusses the effectiveness of Renewable energy Input-Output table. The last section showed analysis results. The paper ends with conclusions.

Renewable Energy Policy in Korea

The Korean government has embarked to promote renewable energy. However, the results of this promotion have been rather modest. Korea produced renewable energy in the amount of 3.757 million tons of oil equivalent (Mtoe) or 1.52% of the total primary energy supply (TPES) in 2010, as can be seen in Table 1. This share is one of the lowest among OECD countries.

The Korean government introduced the *Alternative Energy Development Promotion Act* in 1987 to promote alternative energy. This act was revised in 1997 and renamed as the *Alternative Energy Development, Use and Promotion Act*. And it was amended in 2004. This act was designed to support among others commercialization of renewable energy, R&D in renewable energy, establishment of standards in renewable energy equipments and parts, and establishment of an institution on renewable energy statistics. This act contains a provision to formulate and implement the so-called *Basic Plan for Development, Use and Deployment of* renewable energy *Technology* every five years. The *2nd Basic Plan* of 2003 aimed to raise the production share of renewable energy in TPES to 5% by 2011 and 9% by 2015. The Korean government pushed ahead various policies to disseminate wind power, photovoltaic, small hydro, bio-fuel, etc. In addition, Korea introduced the feed-in-tariffs (FIT) scheme to accelerate the deployment of renewable energy in 2002. This scheme has been financed by the so-called *Electric Power Infrastructure Fund* which was established in 2001 and which has been generated by a levy of 3.7% on electricity bills of all consumers in Korea.

Table 1: RES production in Korea, 2005-2013

Unit: Mtoe

	2005	2007	2008	2009	2010	2012	2013
TPES	210.10	222.15	226.95	229.18	246.52	263.44	262.23
Renewables	2.484	3.111	3.342	3.433	3.757	4.883	5.394
Hydro	0.316	0.312	0.264	0.242	0.317	0.341	0.369
Geothermal	0.003	0.011	0.016	0.022	0.034	0.065	0.093
Photovoltaics	0.00	0.006	0.025	0.049	0.092	0.095	0.128
Solar (thermal)	0.035	0.029	0.028	0.031	0.030	0.026	0.025
Wind	0.011	0.032	0.037	0.059	0.070	0.079	0.098
Biofuel	0.385	0.551	0.580	0.691	0.719	1.277	1.396
Waste	1.733	2.169	2.390	2.332	2.488	2.998	3.243
Other sources		0.001	0.002	0.007	0.007		0.042

Source: IEA, Energy Balances of OECD countries, 2014 edition

The 4th *Basic Plan for Development, Use and Deployment of renewable energy technology of 2014* revised the targets of the 3rd Basic Plan for the production share of renewable energy to 5.0% in TPES by 2020 and 11% in TPES by 2035 (Table 2). Annual growth rate of renewable energy during 2014~2035 is 6.2%. 13.4% of generation will be supplied by renewable energy on 2035. The 3rd Basic Plan contains to introduce Renewable Portfolio Standards (RPS)

scheme starting from 2012 and to phase out the FIT scheme by 2011. The main reason for the shift of the renewable energy promotion scheme was a rapidly growing amount of FIT payments. Under the RPS scheme, 14 state-run and private power utilities with a capacity more than 500 MW are obliged to generate 4% of electricity with renewable energy by 2015 and 10% by 2022. The Korean government hopes with this scheme to increase the generation capacity with renewable energy by 350 MW yearly until 2016 and by 700 MW yearly until 2022.

Table 2: Targets of 4th Basic Plan for Development, Use & Deployment of Renewable Energy Technology

Unit: % in TPES

	2012	2014	2025	2035	Annual growth rate(%)
Solar (thermal)	0.3	0.5	3.7	7.9	21.2
Solar (photovoltaic)	2.7	4.9	12.9	14.1	11.7
Wind power	2.2	2.6	15.6	18.2	16.5
Bio fuels	15.2	13.3	19.0	18.0	7.7
Hydro	9.3	9.7	4.1	2.9	0.3
Geothermal	0.7	0.9	4.4	8.5	18.0
Tide (ocean)	1.1	1.1	1.6	1.3	6.7
Waste	68.4	67.0	38.8	29.2	2.0

It is to note that there are differences in the statistics on production of renewable energy and TPES for the years 2008 and 2010. First, the Korean energy statistics are overestimated mostly due to double-counting of backflows of naphtha from the petrochemical sector to refineries. (Park, 2005) Second, the Korean renewable energy statistics does not follow the established practices of the International Energy Agency (IEA). For instance, it assumes some of exhaust gas recaptured of the fossil fuel origin to raise energy efficiency as renewable energy. The Korean renewable energy production figure with 6.36 Mtoe in 2008 is by about 3 Mtoe higher than that of the IEA statistics 3.343 Mtoe. Therefore, the renewable energy production targets of the Korean government are unrealistic.

Literature Survey

Kang(2009) analysed that Government financial support of 107.4 Trill. Won of 2009~2013 will induced 1,180 Thous. ~ 1,470 Thous. persons of employment. It is 2.20~2.74 persons/year/1 Bill. Won. This analysis used Input-Output method. KNREA(2010) used Input-Output table 2008, this table has eight industrial sector of Agriculture/Fishery/Forest, Manufacturing, Service, Electricity/Gas/Water Supply, Research, Renewable Energy, Non-Classified. This research analyzed induced production effect and induced employment effect by Government financial expecditure for renewable energy. In addition they estimated employmenet effect by Propensity Score Matching method. Small number of industrial sector classifications will hide trade goods and services among industrials. Micro data information will not supplied anymore under these eight industrial sector classifications. This analysis mentioned that Renewable energy is the new industry and it makes double of employment compared with conventional industry. This analysis showed that employment effect per 1MW in renewable energy is bigger than conventional sector. Employmenet effect 3.6 persons in wind, 13.5 persons in bio and 27.3 persons in photovoltaic when each renewable energy source generate 1MW electricity. However conventional thermal power induced 0.3 persons when it generates 1MW electricity.

KDI and KLI(2012) used Input-Output method as analysis method. This researched found that among 350 sectors of Input-output industry classification, 66 sectors are green sector. This results showed that Government financial support of 89.9 Trill. Won of 2009~2013 will induced 1,213 Thous. persons of employment. It is 2.70 persons/year/1 Bill. Won. 5 year Plan for Green Growth said that Government financial support of 89.9 Trill. Won of 2009~2013.

Bezdek(2007) analyzed that in 2006 rapid growth of Renewable Energy and Energy Efficiency(EE) induced employment opportunity more than 450,000. He also showed that induced employment of photovoltaic and Wind is 15,700 persons/ 1 Bill. USD and 12,270 persons/1 Bill. USD respectively. Pollin et al.(2008) analyzed that effect in employment from 10 Bill. USD investment in Green Growth of US is 2 million persons. This effect was devided by

direct effect, indirect effect and induced effect. Direct effect is 935,200 persons, indirect effects is 586,000 persons and induced effects is 496,000 persons.

Ministry of Environment, Japan(2008) estimated performance of industry promotion and employment of RE. In this results Input-Output Table 2000 of intermediate sector 104 is used. Photovoltaic, wind, small hydro, geothermal. Biomass, solar heat, the other heat were considered in analysis. Ministry of Environment set assumptions for amount of inverstment for each renewable energy sources. Estimation results showed that investment of 3.2 Trill. Yen of photovoltaic induced 8.7 Trill. Yen of production and 460 Thous. persons of employment in 2020. Investment for renewable energy have positive effect in industry promotion and employment and indirect effect of employment in other manufacturing, commercial, R&D sector.

Methods

Bank of Korea (BOK) uses financial statements and survey for buying and selling of each company and industry when they make Input-Output Table. Methodology of BOK is one of reliable method to build Renewable Input-Output table. Financial statements, which show material flows of each company, are most significant and reliable information in building of table. Financial statements of representative company in each RE source provide micro information for wages, surplus, taxes, sales, and input structure in production.

At the first stage to make Renewable Energy Input-Output Table, representative company must be pointed in each RE source. This representative company produces neither co-product nor by-product of renewable energy source but one product of RE source. This company also publishes its financial statements regularly in public. At the second stage, financial statements of each company must be collected in same fiscal year. At the third stage, thermal power sector of Input-Output table will be divided Renewable Energy sector and Non- Renewable Energy sector. After this, it is arrangement process that Renewable Energy Input-Output table is to be balanced in total input and total output.

Table 3: Estimation result for input coefficient of photovoltaic equipment

		021
		PV generation system
001	agriculture	0.000000
002	mining	0.002009
003	food	0.000000
004	textile	0.000000
005	pulp	0.000000
006	petoleum coal products	0.002009
007	organic basic chemical products	0.001724
008	Inorganic basic chemical products	0.011492
009	Synthetic resins	0.009182
010	Synthetic rubber	0.000862
011	chemical final products	0.007458
012	glass	0.086207
013	cement	0.000000
014	ceramic	0.001147
015	iron	0.057339
016	Nonferrous metal ingots	0.186650
017	Primary nonferrous metal products	0.189260
018	metal products	0.022936
019	general machinery	0.011468
020	electric machinery	0.035550
021	PV generation system	0.000000
022	Precision instruments	0.000000
023	transportaion instruments	0.000000
024	Misc. manufactured products	0.020089
025	electricity	0.045951
026	water	0.002871
027	construction	0.000000
028	commerce	0.000000
029	transport	0.035867
030	communication	0.000000
031	finance	0.000000
032	real estate	0.000000
033	service	0.000000
034	Office supplies	0.000000
035	Business consumption expenditures	0.000000
036	Total intermediate input	0.730070
037	Compensation of employees	0.040177
038	Operating surplus	0.000000
039	Depreciation of fixed capital	0.229753
040	Taxes on production-subsidies	0.000000
041	Total value added	0.269930
042	Total input	1.000000

In Korea, renewable energy companies are small and they did not publish financial statements in public. Therefore, other data published by the Government sectors are used. MKE publishes “Survey of Renewable Energy Industry” in every year from 2010. This survey contains sales, employment, import, export, and investment of each renewable energy source such as photovoltaic, wind, geothermal, etc. Input-Output table of Korea has also energy sector. Based on Input-Output table of Korea, distribution of electricity and heat produced by renewable energy among economic sectors will be researched. In addition “Annual Energy statistics”, “Energy balance table” are used as raw data.

Table 4: Induced production and employment from photovoltaic equipment

Unit: times, persons

	induced production	induced employment
1 agriculture	0.003	0
2 mining	0.004	0
3 food	0.005	0
4 textile	0.002	0
5 pulp	0.008	0
6 petoleum coal products	0.029	0
7 organic basic chemical products	0.013	0
8 Inorganic basic chemical products	0.010	0
9 Synthetic resins	0.011	0
10 Synthetic rubber	0.001	0
11 chemical final products	0.019	1
12 glass	0.083	2
13 cement	0.000	0
14 ceramic	0.003	0
15 iron	0.118	1
16 Nonferrous metal ingots	0.140	1
17 Primary nonferrous metal products	0.154	3
18 metal products	0.031	2
19 general machinery	0.015	1
20 electric machinery	0.032	1
21 PV generation system	1.001	5
22 Precision instruments	0.001	0
23 transportaion instruments	0.004	0
24 Misc. manufactured products	0.017	0
25 electricity	0.079	1
26 water	0.004	0
27 construction	0.002	0
28 commerce	0.028	3
29 transport	0.046	3
30 communication	0.005	0
31 finance	0.015	1
32 real estate	0.005	0
33 service	0.036	4
34 Office supplies	0.001	0
35 Business consumption expenditures	0.009	0
Total	1.932	29

Financial statements and factory cost reports of Korean photovoltaic equipment company, and Input coefficient of photovoltaic equipment by ESRI Japan (2010) are used to estimate input coefficient of photovoltaic equipment. ESRI Japan (2010) revised estimatation result of life cycle cost analysis for Renewable Energy industry. ESRI Japan (2007) already estimated life cycle cost and input structure of renewable energy industry such as photovoltaic, hybrid car, Bio fuel, CCS (Carbon Capture Storage), Forest management.

Photovoltaic IO table 2010 is generated based on Input-Output Table 2010 of Korea(Published 2014). Sales is used as raw data for photovoltaic equipment industry. Producer price IO table is used. Intermediate sector is 35 sectors. Photovoltaic equipment is included in ‘Electrical equipment and supplies’. New row and column for ‘photovoltaic equipment’ will be divided from ‘Electrical equipment and supplies’. Electrical equipment and supplies are from ‘096 Motors, generators, capacitors and rectifiers’ to ‘105 Household electrical appliances’. Input coefficient of photovoltaic equipment is based on financial statements and cost reports of photovoltaic equipment company and input coefficient of ESRI (2007). ESRI (2007) surveyed input and output structure of renewable energy industries such as photovoltaic, hybrid car, bio fuel, Carbon Capture Storage (CCS), and forest management, and presented its input coefficient. MOE

of Japan (2008) analyzed induced effects from Government promotion in renewable energy based on Japanese Input-Output table 2000.

Input-Output table 2010 with Photovoltaic manufacturing sector was made following steops. First, sales of 'photovoltaic equipment' is excluded from total input of 'Electrical equipment and supplies'. Second, financial statements and cost reports of Korean photovoltaic equipment company is applied to column of photovoltaic equipment. Third, column of photovoltaic equipment industry from 1st step is compared with photovoltaic eqiipment input coefficient of ESRI (2010). Fourth, Amount of input from each industry is estimated.

In Input-Output Table of 2010 by BOK, GDP is 1,244,630.5 Bill. Won, Total intermediate input is 1,999,278.8 Bill. Won and Total input is 3,243,909.4 Bill. Won.

Major figures of photovoltaic equipment industry in 2010 are follows. Sales of photovoltaic equipment is 5,909.7 Bill. Won in renewable energy industrial survey results of 2010 by MOE and KEMCO (2011). It was 3.3 Bill. Won. of 2003 and 441.1 Bill. Won. of 2007. Sales of Electrical equipment and supplies is 268,918 Bill. Won. Value added of Electrical equipment and supplies 56,614 Bill. Won. Estimation result for input coefficient of photovoltaic equipment was showed in Table 3. Estimation results of input structure of photovoltaic equipment are follows. Intermediate total of photovoltaic equipment is 2,278 Bill. Won. Value added total of photovoltaic equipment is 842 Bill. Won. Total input of photovoltaic equipment is 3,120 Bill. Won. Export in photovoltaic equipment industry is 45.8 Bill. USD of 2010. It was 0.07 Bill. USD of 2004 and 0.78 Bill. USD of 2010. These values will be used control total in making photovoltaic Input-Output table. Photovoltaic equipment is used in intermediate demand(electricity utility) and final demand(fixed capital formation and export). Therefore Total intermediate demand will be 700 Bill. Won. It was calculated from Total production, Fixed capital formation, and Export.

Induced analysis both production and employment for investment or deployment policy in renewable energy will be estimated with Renewable Energy Input-Output table. This induced analysis looks like typical Input-Output analysis. Empirical analysis estimated that final demand of 10 Bill. Won for photovoltaic equipment induced production of 19.321 Bill. Won in Korea. This is 1.932 times of final demand. Induced production in Primary iron and steel products (1.181 Bill. Won), Primary nonferrous metal ingots (1.404 Bill. Won), Primary nonferrous metal products (1.540 Bill. Won) are bigger than 1 Bill. Won. Most industries has smaller than 1 Bill. Won induced production. This induced effect is smaller than previous research such as Kang (2009, 2.20~2.74 persons/years/Bill. Won.), and KDI and KLI(2012, 2.70 persons/year/Bill. Won.

Employment statistics of renewable energy from 'Rrenewable energy industrial survey' of MKE(2011) exclude 'Electrical equipment and supplies' of employment table. Photovoltaic employment and RE employment of 2010 from 'Rrenewable energy industrial survey' of MKE(2011) are 8,579 persons. It was 160 people of 2004 and 1,156 people of 2010. Final demand of 10 Bill. Won for photovoltaic equipment induced 29 persons of additional employment in Korea (= 2.9 persons/Bill. Won). Induced employment in photovoltaic equipment is the biggest, 5 persons. The tertiary industry, such as Commercial, Transportation, and Service, has bigger induced employment. Some industries have zero of induced employment.

Conclusions

The Korean Government install a couple of policy to promote RE industry and RE share in TPES. Photovoltaic Input-Output table 2010 have a chance to evaluate this Government expenditure. In addition, Photovoltaic Input-Output table allows evaluating amount of induced effect in production and employment from growing of renewable energy industry.

Empirical analysis shows that induced production and employment from additional final demand in photovoltaic equipment industry is similar with that of other industry in Korea. Major related industry is iron and steel industry. Photovoltaic equipment industry stimulate other industry which Korea has relative priority. Photovoltaic equipment industry has potential to grow in industry sector like electricity industry, vehicle industry, construction and civil engineering industry, etc. For example, additional demand in photovoltaic power equipment induced 1.932 times of production in Korea. In aspect of induced employment from additional final demand in RE industry is not huge. Photovoltaic equipment industry is not a labour intensively industry but a capital intensively industry. It has small positive effect on new employment in labour market. And labour force moves from conventional generation sector to photovoltaic generation sector. Final demand of 1 Bill. Won for photovoltaic equipment induced 2.9 persons of

additional employment. Photovoltaic equipment industry will not generate more income than such ones in other economic sectors. As far as the employment effect of photovoltaic equipment industry is concerned, job creation will also depend on the productivity of such industry. Job creation will be desirable only under increasing overall income.

Published RE industry micro data by Government or related institution is needed to estimate induced effect and to assess the results of policy performance. Input structure for RE sources is necessary in induced effect analysis. Future indueced effect analysis must include maintenance and repair. This research will present bigger figure of induced production and employment.

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