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Abstract

The Korean government announced a so-called energy transition policy in that it shift away from nuclear power toward renewables in 2017. This study compares the impacts of existing and new energy policies on electricity price, examines the new policy's effects on the manufacturing sectors. The estimation result of the difference in power generation costs between two policies shows increase of 12.2% in electricity price in new than old one. The rise in electricity price result in a drop of about 0.23% point in profitability for the total manufacturing sectors, which in general do not show much of a decrease in operating profit margin from rising costs. However, there are many small-sized firm with less than 1% operating profit margin, and for these firms, a 0.2% point drop in the operating profit margin will be great. The production is estimated to decrease more than 10% in the electronics and metal industries. When the increase in electricity price become a reality, the impact of increased production costs in manufacturing will have to be minimized through a combination of various policies, as the impact of increased production costs on manufacturing is different for each firm size and sector

Key words

energy transition policy, energy mix, power generation cost, operating profit margin, price elasticity for electricity demand time-varying coefficient, production elasticity of the electricity price

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1. Introduction

The Moon Jae-in Administration announced on December 2017 the 8th Basic Plans for Long-term Electricity Supply and Demand (8th BPLE) which reflects environmental and safety factors in addition to stable power supply and economic efficiency. The 8th BPLE is called the "energy transition policy[1]" in that it shift away from nuclear power toward renewables, unlike the existing BPLE[2]. Further, the policy places priority on strengthening demand management and focuses on steady increase in the use of distributed energy resources[3]. The energy transition policy considered in protecting safety and environmental energy security from natural disasters such as Japan's Fukushima nuclear accident in March 2011, the Gyeongju earthquake in September 2016 and the Pohang earthquake in November 2017 in Korea.

While the policy of moving from nuclear and coal power to renewables and natural gas is widely supported in terms of eco-friendly and safety, there are also problems to realize that policy goal. In particular, the stability of demand and supply of energy is the most important factor to consider in Korea, which has energy-intensive industrial structure and relies on imports for most of its energy. This study focuses on the changes in electricity price among the various changes that may arise from the implement of the energy transition policy and analyzes the impacts of those changes on manufacturing.

When a firm is facing an external shock of a rise in electricity price, it may transfer the increased cost to the price, or it may absorb the cost internally by lowering revenue that much. Of these two strategies, which strategy a firm chooses generally depends on the price elasticity of demand. Firms that produce a product to be elastic will absorb the cost increase internally without transferring to the price because there is more decline in demand due to price increase. On the other hand, firms that produce non-elastic product will maximize profit by transferring cost increase to price while maintaining return. In terms of product competitiveness, the more elastic of a product produced by a firm is, the lower the firm's product competitiveness is. Therefore, the more competitive firms are, the more likely they will externalize the impact of rising cost, and the less competitive they will take an internalization strategy.

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1 Energy transition is defined as a fundamental structural change in the energy sector of a certain country, like the increasing share of renewable energies and the promotion of energy efficiency combined with phasing out fossil energies. The energy transitions differ in terms of motivation and objectives, drivers and governance, and provide a diverse set of challenges and opportunities. (World Energy Council, 2014)

2 The BPLE was established pursuant to Article 25 of the Electricity Utility Act and Article 15 of the Electricity Utility Decree biennially for mid-to long-term forecast of electric power demand and the corresponding installation of more electric facilities. The first Basic Plan for Long-term Electricity Supply and Demand was established in 2002 and whole of eight BPLEs have been released so far. (Ministry of Trade, Industry and Energy, 2017)

3 Distributed energy resources (DERs) refer to small-sized generation facilities (below 40 MW) and generation facilities applicable to points of demand (below 500 MW) with minimal construction of transmission lines. (Ministry of Trade, Industry and Energy, 2017)

While these strategic actions (internalization or externalization) are responses to the direct impact of rising costs on its activities, there are also indirect impacts caused by other economic behaviors. For example, the increase in electricity price can negatively affect a firm's production, resulting in a decrease in product demand caused by the decrease of disposable income in households. As such, the shock of rising costs may have an indirect impact on firms through various channels.

This study focuses on analyzing the direct impacts of changes in electricity price caused by the energy transition policy. In particular, we measures changes in operating profit margin and estimates changes of output and value-added in manufacturing industry.

The remainder of the paper proceeds as follows. Section 2 analyzes the changes in power generation costs and electricity price between the new and the previous energy policy. Section 3 examines the impacts of changes (rising) in power charges on profitability and production of manufacturing, and draws conclusions and implications in the last section 4.

2. Energy Mix and Changes in Electricity Price

2.1 Energy Mix of the 7th and 8th BPLEs

The 8th BPLE set the basic direction of energy mix to be economical, safe and clean energy mix of phasing out the use of nuclear energy and coal while increasing the shares of renewable energy and natural gas (LNG). The total install capacity of 8th plan was projected to increase by 43.4% from 117.0 GW at 2017 to 167.8 GW in 2029 as shown in Table 1, which compares the energy capacity mix between 7th and 8th BPLEs.

The capacity of 7th plan in 2029 is expected to be 163.9GW, which is only 4GW(2.4%) larger than the capacity of the same year in the 8th plan, but there is a significant difference between the two plans in the energy mix. In 8th plan, while the combined renewable and LNG capacity was expected to rise from 41.6% to 59.9% of total capacity, it was projected that the combined share of nuclear and coal reduced from 50.8% to 35.9%. In contrast, the 7th plan projected the combined share of renewable and LNG at 46.2% in 2029, but the share of coal and nuclear at 50.3% in the same year. As expected, the share of renewable increase to 20.1% by 2029, but remain 11.6% points lower than 31.7% in 8th plan.

As above, the 8th plan resulted in structural changes in energy mix. In particular, instead of significantly lowering the share of nuclear capacity compared to the 7th plan, the share of renewable capacity has been raised to that level. In 2029, the share of renewable of the 8th plan was expected to be 31.7%, 11.6% points higher than the 20.1% of the 7th plan, and the share of nuclear 11.2% lower than the 23.4% of the 7th plan. Therefore, the 8th plan is regarded as "alternative energy transition policy" in that it aims to fundamentally change the previous energy mix centered on nuclear and coal to renewable energy and gas.

Table 1 Comparison of energy capacity mix between 7th and 8th BPLEs

	Nuclear	Coal	LNG	Oil	Pumped Storage	Renewable	Total
2017 year in the 8th(MW)	22,529	36,920	37,353	4,151	4,700	11,316	116,968
(Share %)	(19.3)	(31.6)	(31.9)	(3.5)	(4.0)	(9.7)	(100.0)
2029 year in the 8th (MW)	20,400	39,921	47,460	1,391	5,500	53,126	167,798
(Share %)	(12.2)	(23.8)	(28.3)	(0.8)	(3.3)	(31.7)	(100.0)
2029 year in the 7th (MW)	38,329	44,018	42,736	1,195	4,700	32,890	163,868
(Share %)	(23.4)	(26.9)	(26.1)	(0.7)	(2.9)	(20.1)	(100.0)

Source: Ministry of Trade, Industry and Energy(2015), The 7th Basic Plan for Electricity Supply and Demand (2015-2029); Ministry of Trade, Industry and Energy(2017), The 8th Basic Plan for Electricity Supply and Demand (2017-2031);

2.2 Changes in Electricity Price Caused by of the 7th and 8th BPLEs

The electricity price reflects the significant difference in energy capacity mix, which is acting as a factor in changing power generation costs, between two plans. Table 2 shows the estimating process for power generation cost based on the capacity of each energy source in the 7th plan.

Table 2 Power generation costs for 2029 year by 7th BPLE

	Nuclear	Coal	LNG	Oil	Pumped Storage	Renewable	Total
(A) Capacity (MW)	38,329	44,018	42,736	1,195	4,700	32,890	163,868
(B) Operation rate (%)	76.8	73.6	12.0	-	9.3	26.7	
(C) Transaction Volume (GWh)	257,875	283,753	44,780	-	3,812	83,554	673,774
(D) Unit price (Won/kWh)	60.7	78.5	111.6	165.5	107.6	58.4	
(E) Electricity sales amount (Bill. Won)	15,648	22,272	4,998	-	410	4,878	48,206
(F) Volume share (%)	38.3	42.1	6.6		0.6	12.4	100.0

Note: 1) LNG includes collective energy, coal included both anthracite and bituminous coals.
2) Operation rate = (C)/(A)*365days*24hours)*100 for nuclear, coal, and pumped storage, LNG's operation rate= (C)*1000/(A)*365days*24hours)*100, and the renewable operation rate is the value that achieves the 8th plan's power generation target (20% of total, 134,961GWh).
3) Transaction volumes(C) = (A)*365days*24hours*(B)/100000 for of nuclear, coal, pumped storage and renewable. 4) Electricity sales amount (E) = (C)*(D)/100.

In order by row, Capacity (A) represents the generation mix outlook for 2029 year by nominal capacity based on the installed capacity in 7th plan. In the operation rate (B), for nuclear, coal, and pumped storage, it is the average of the past 3 years (2015~2017) for each capacity. The operation rate to achieve the renewable generation target of the 8th plan is applied for renewable, and the operating rate of LNG is calculated by using the related capacity (A) and transaction volume (C) as described in note of table 2. The transaction volumes (C) of nuclear power, coal, pumped storage, and renewable are calculated by using the related capacity and operation rate. For LNG, reflecting the characteristic that is in charge of peak demand, the transaction volume(= 44,780Wh) is derived by subtracting the sum of the power trading volume of nuclear, coal, pumped storage, and renewable from the total transaction volume (673,773GWh).

In addition, the operation rate of LNG is calculated by using this transaction volume and the related capacity. Where the total transaction volume are taken into account the transmission and distribution loss rate (2.44%) in the 2029 consumption outlook of the 8th plan. For the normal unit price, which is one of the important assumptions, the actual price of 2017 is applied. However, in the case of renewables with the goal of lowering the generation cost by 35.5% in the 8th plan, 58.4 won/kWh, which is 65.5% of the actual price in 2017 (90.5 Won/kWh), is applied. Electricity sales amounts (E) are calculated by multiplying the transaction volume (C) by unit price (D). Finally, the total cost of power generation for the 7th plan, assuming the maintenance of the existing policy, is estimated to be 48,206 Billion Won.

On the other hand, Table 3 shows the calculated power generation costs for 2029 year by of the energy mix of the 8th BPLE. The result is based on the same formula and assumptions as Table 2 above, except for assumptions for the operating rate of coal, coal and LNG unit prices. The coal operation rate is assumed to be 70%, 3% lower than 73.6% of the 7th plan. This takes into account the fact that the 8th plan may further reduce the proportion of coal by introducing an environmentally friendly power dispatch which the impacts on the environment (greenhouse gases, fine dust etc.) as well as the economy should be considered comprehensively in the decision making the dispatch order of power. The unit price of coal is adjusted upward 15% increase and LNG unit price is lowered 90% of 7th plan. This adjustment is to take into account the intention of the 8th plan to induce competition between LNG through reflecting environmental costs, adjusting taxes, and calculating equalized power generation costs.

As a result of applying the premise of the 8th plan, the total cost of power generation is estimated at 54,082 Billion Won, 12.2% higher than 48,206 Billion Won in the 7th plan, and this can be regarded as the additional power generation costs under the energy conversion policy.

In fact, Korea's electricity prices tend to be determined by policy rather than by reflecting fuel costs, so it may be a separate matter to increase power generation costs to increase electricity prices. Nevertheless, it is assumed that there is a greater justification for the future that electricity prices should be linked to fuel costs, and that for the convenience of analysis, an increase in power generation costs will lead to a rise in electricity prices entirely. This means that the profit structure of Korea Electric Power Corporation (KEPCO), which produces all of Korea's electricity, is the same as in 2017, as well as the assumption that inflation does not reflect.

Table 3 Power generation costs for 2029 year by 8th BPLE

	Nuclear	Coal	LNG	Oil	Pumped Storage	Renewable	Total
(A) Capacity (MW)	20,400	39,921	47,460	1,391	5,500	53,126	167,798
(B) Operation rate (%)	76.8	70.0	36.6	-	9.3	29.0	
(C) Transaction Volume (GWh)	137,245	244,796	152,311	-	4,460	134,961	683,270
(D) Unit price (Won/kWh)	60.7	90.3	100.4	165.5	107.6	58.4	
(E) Electricity sales amount (Bill. Won)	8,328	22,096	15,298	-	480	7,880	54,082
(F) Volume share (%)	20.1	23.8	23.0		0.7	20.0	100.0

Note: The formula used is the same as Table 2. However, for the operation rate of coal, 70%, which is 3.6% point lower than 73.6% of the 7th plan, is assumed, for the coal's unit price, the price 90.3 Won/kWh increased by 15% of the 7th plan, and for the LNG's unit price, 90% of the 7th plan is applied.

The following section analyze the profitability of manufacturing and the impact on changing prices by setting a base scenario in which 12.2% of the estimated additional costs of power generation leads to an rise in electricity prices. In this regard, Jang et al. (2017) expected that the eco-friendly policies would further rise in the electricity price for household by 11.9% in 2030 compared to maintaining existing policies. The research assumed that an additional increase in power generation costs would lead to a rise in electricity prices as in this study, but detailed assumptions of existing and eco-friendly policies are set differently.

3. The Effect of Changes in Electricity Price on Manufacturing

3.1 Changes in Operating Profit Margin (OPM)

The changes of electricity price affect the profits and production through the change of cost for firms using electricity power in the production process. This section analyzes the effect of a rise in electricity prices on operating profit by the detailed manufacturing sectors. The increase in production costs resulting from the rise in electricity prices can be transferred to product prices, but the degree of transfer will vary depending on the characteristics of firms and manufacturing sectors. To simplify the analysis, it is assumed that an increase in electricity prices does not transfer to product prices, but all acts as a rise in production costs, thereby reducing operating profit margin (OPM). Where OPM is the same as the usual concept as defined by the ratio of operating income to sales revenue.

In reality, many firms will minimize the decline in operating profit by absorbing part of the rise in electricity price as a cost and partly transferring the other part to product price. In this way, if the product price increases, the production cost of other industries increases, and as a result, the overall level of price increases, adding to the indirect effect of deteriorating operating profit. Although this indirect effect will not be large, the deterioration of the operating profit that actually occurs will be smaller than the analysis result of this study.

We analyze manufacturing sectors at the division level (2-digit) of the Korean standard industrial classification (KSIC), while is examined at the class level (3-digit) for the manufacture of electronic components, computer, radio, television and communication equipment and apparatuses (C26). Table 4 shows the numbers of firms and workers, electric costs, operating profit margins, and the proportion of normal operating firms[4].

In 2016, the manufacturing average of the ratio of electricity costs to total cost is 1.9%. By sector, 8 (C13, C16, C17, C20, C22, C24, C23, C26) of 25 sectors at the 2 digit level, 3 (C261, C262 and C266) of 6 sectors at the 3 digit level exceed the manufacturing average. In particular, C17 pulp, paper and paper products account for the highest ratio of 4.0%, followed by C23 other non-metallic mineral products 3.9% and C24 basic metal products 3.8%.

The average OPM of the manufacturing is 6.9% in 2016, and 15 of the 26 industries exceeded the manufacturing average. In particular, the C12 tobacco records the highest OPM of 53.8%, followed by C11 beverage 27.5%, C21 pharmaceuticals, medicinal chemicals and botanical products 19.6%, but the C266 magnetic and optical medium and C31 other transport equipment show negative, -3.2% and -1.1% respectively. .

In firms with less than 1% OPM, C19 coke, hard-coal and lignite fuel briquettes and refined petroleum products accounted for 35.0% of the industries with the highest proportion, followed by 27.7% of C26 electronic components, computer, radio, TV and communication equipment and apparatuses. The C21 medical substance and pharmaceutical manufacturing industry accounted for 23.0% of the total, and the manufacturing average is 17.6%.

On the other hand, Table 5 shows the result of calculating the difference between the actual OPM and the OPM that assumed 12.2%, which is the difference between the electricity prices of the 7th and 8th plans estimated in the previous section, for every sectors. The overall OPM of manufacturing decreases 0.22%p, 0.23%p for firms with more than 300 employees, and 0.21%p with less than 300 employees.

The decline in OPM is greater in firms with more than 300 employees, but the OPM itself is lower in firms with less than 300 employees, so the increase in electricity price will have a greater impact on small firms. For example, for the semiconductor industry, the average OPM of the industry is very high at 11.7%, and it is estimated that the OPM drops by 0.35%p due to the increase in electricity prices. Looking at the impact of the increase in electricity prices by firm size, the OPM for firms with more than 300 employees drops by 0.37%p from 12.4%, while the OPM for those with less than 300 employees decrease by 0.17%p from 0.40%. Although the decline in OPM of firms with more than 300 employees is twice as great as those with less than 300 employees (0.38%p vs 0.17%p), considering that the firms with less than 300 employees have very low OPM, the real impact of the increase in electricity prices is very significant. In addition, as the proportion of firms with less than 1% OPM in the semiconductor

4 According to financial statement analysis by Bank of Korea(BOK), the ratio of interest expense to sales in the manufacturing is 0.9% in 2017. With reference to this, we consider a firm that produces an operating profit margin covering the interest costs of more than 1% as a normal operating firm.

industry is 30%, the impact of rising costs is greater than the actual decline in OPM for small firms, which could put many firms on the brink of survival.

In fact, large firms can maintain profitability by transferring cost increases to prices because they have the ability to set prices, but small and medium-sized firms will not be able to set prices because they are mostly subcontractors and produce competitive products, so they will likely internalize the impact of higher costs and lead to lower returns. Therefore, if electricity price rise, large firms will take an externalization strategy to reduce production, reducing production orders for smaller subcontractors, and small and medium-sized firms are likely to suffer from double whammy of having to deal with production reductions as well as worsening returns from rising costs.

3.2 Changes in production

This session estimates the effect of rising electricity prices on manufacturing production. We reflects a mechanism in which an increase in the electricity price raises the price of a manufacturing product, which acts as a decrease in demand for the product, resulting in a decrease in the production and electricity demand of the manufacturing. In the actual analysis, first, the effect of price on electricity demand is estimated, and then the relationship between electricity demand and manufacturing production is identified to grasp the impact on production. The reason for the two-step process is that there is no the reduced model for production or demand, while the electricity demand function has a well-defined model. Using a model defined as a short form makes it easier and more accurate to estimate electricity demand.

3.2.1 Model

We specify a reduced model for electricity demand function. The reduced model as shown (1) is used by Chang et al. (2014) and Park and Hong (2018). The model is also used to analyze and predict energy demand in Korea Electric Power Corporation (KEPCO) and Korea Gas Corporation (KOGAS), which are public institutions responsible for the stable supplies of major energies such as power and gas at the national level.

$$\mathrm{y}_t^{(i)} = \log\left(\frac{\mathrm{MPS}_t^{(i)}}{\mathrm{MED}_t^{(i)}}\right) = \alpha^{(i)} + \beta_t^{(i)}\log MIPI_t^{(i)} + \gamma^{(i)}\log PRC_t^{(i)} + \delta TE_t^{(i)} + \varepsilon_t^{(i)} \quad (1)$$

for the monthly of *t*, *t* =1, …, *T* and the sub-sector in manufacturing of *i*, *i* =1, …, m, where $MPS_t^{(i)}$ is the monthly electricity sales volume, $MED_t^{(i)}$ is the effective days in month, $MIPI_t^{(i)}$ is the monthly industrial production index, $PRC_t^{(i)}$ is the real price index for industrial electricity and $TE_t^{(i)}$ is the monthly temperature effect.

In our specification, we contain following features found in recent empirical studies on electricity demand. First, it includes the time-varying coefficient $\beta_t^{(i)}$ to consider that long-run elasticities of demand for electricity are not stable over time. The empirical findings of Chang et al. (2014) reveal dramatically increasing income/output elasticities over the sample periods in each sector. Specifically, they find demand for electricity to be very income inelastic but becoming more income elastic over time.

Table 4 Electricity cost and Operating Profit Margin by sectors in Manufacturing Industry (2016 year)

KSIC Code	Korea Standard Industrial Category	Number of firms	Number of employees	Ratio of electricity cost to total cost (%)	Operating Profit Margin (%)	Firms with less than 1% OPM	
						Number of firms	Share (%)
C10	Food products	5,014	195,940	1.3	10.3	1,043	20.8
C11	Beverage	260	15,628	1.5	27.5	49	18.8
C12	Tobacco	9	2,140	1.0	53.8	-	0.0
C13	Textile; except clothing	3,134	88,904	3.2	4.8	480	15.3
C14	Apparel, clothing accessories and fur articles	2,421	63,442	0.2	6.6	304	12.6
C15	Tanning and dressing of leather, luggage and footwear	775	19,699	0.8	7.5	137	17.7
C16	Wood products of wood and cork; except furniture	864	20,070	2.1	2.9	137	15.9
C17	Pulp, paper and paper products	1,812	59,915	4.0	7.3	328	18.1
C18	Printing and reproduction of recorded media	1,194	29,523	1.7	5.1	177	14.8
C19	Coke, hard-coal and lignite fuel briquettes and refined petroleum products	137	11,176	1.5	7.4	48	35.0
C20	Chemicals and chemical products except pharmaceuticals, medicinal chemicals	2,787	132,868	3.7	12.3	534	19.2
C21	Pharmaceuticals, medicinal chemicals and botanical products	505	38,536	1.2	19.6	116	23.0
C22	Rubber and plastic products	6,138	227,631	2.3	5.7	887	14.5
C23	Other non-metallic mineral products	2,603	87,108	3.9	9.8	439	16.9
C24	Basic metal products	2,921	140,209	3.8	3.7	580	19.9
C25	Fabricated metal products; except machinery and furniture	9,501	273,465	1.6	6.1	1,233	13.0
C26	**Electronic components, computer, radio, TV and communication equipment and apparatuses**	**3,084**	**371,523**	**2.2**	**6.4**	**1,055**	**27.7**
C261	Semiconductor	377	114,135	3.3	11.7	116	30.8
C262	Electronic components	1,810	168,289	2.6	2.8	461	25.5
C263	Computers and peripheral equipment	270	9,040	0.4	3.4	82	30.4
C264	Telecommunication and broadcasting apparatuses	1,039	60,367	0.4	3.0	324	31.2
C265	Electronic video and audio equipment	303	19,554	0.3	8.1	69	22.8
C266	Magnetic and optical medium	5	138	3.3	-3.2	3	60.0
C27	Medical, precision, optical instruments, watches and clocks	2,317	85,271	0.6	4.8	501	21.6
C28	Electrical equipment	4,248	189,230	0.9	3.1	884	20.8
C29	Other machinery and equipment	9,416	316,519	0.9	5.3	1,510	16.0
C30	Motor vehicles, trailer and semitrailers	4,666	354,504	0.9	7.0	867	18.6
C31	Other transport equipment	1,589	163,831	0.8	-1.1	336	21.1
C32	Furniture	1,191	27,802	0.9	7.6	175	14.7
C33	Other manufacturing	1,045	26,462	1.0	8.7	198	18.9
C34	Repair of industrial machinery and equipment	717	21,781	0.2	8.5	151	21.1
	Manufacturing	**69,068**	**2,963,237**	**1.9**	**6.9**	**12,169**	**17.6**

Source: Statistics Korea, 2016 Mining and Manufacturing Survey.

Table 5 Estimated drop in OPM by increases in 12.2% electricity price

KSIC Code	Korea Standard Industrial Category	Total		More than 300 employees		Less than 300 employees	
		Drop (%p)	2016 OPM (%)	Drop(%p)	2016 OPM (%)	Drop (%p)	2016 OPM (%)
C10	Food products	0.14	10.3	0.13	15.8	0.15	9.3
C11	Beverage	0.13	27.5	0.13	37.6	0.13	23.9
C12	Tobacco	0.06	53.8	0.04	52.2	0.09	57.7
C13	Textile; except clothing	0.37	4.8	0.75	-4.1	0.35	5.2
C14	Apparel, clothing accessories and fur articles	0.03	6.6	0.01	13.1	0.03	4.6
C15	Tanning and dressing of leather, luggage and footwear	0.09	7.5	0.07	-5.2	0.09	7.7
C16	Wood products of wood and cork; except furniture	0.25	2.9	0.76	-13.2	0.19	4.7
C17	Pulp, paper and paper products	0.45	7.3	0.64	13.8	0.41	5.7
C18	Printing and reproduction of recorded media	0.20	5.1	0.00	-320.7	0.20	5.3
C19	Coke, hard-coal and lignite fuel briquettes and refined petroleum products	0.16	7.4	0.17	6.7	0.05	14.8
C20	Chemicals and chemical products except pharmaceuticals, medicinal chemicals	0.39	12.3	0.38	14.8	0.40	9.8
C21	Pharmaceuticals, medicinal chemicals and botanical products	0.12	19.6	0.14	18.2	0.11	20.0
C22	Rubber and plastic products	0.26	5.7	0.26	6.0	0.27	5.6
C23	Other non-metallic mineral products	0.43	9.8	0.87	16.0	0.33	8.3
C24	Basic metal products	0.45	3.7	0.53	4.0	0.34	3.4
C25	Fabricated metal products; except machinery and furniture	0.19	6.1	0.13	7.1	0.20	5.9
C26	**Electronic components, computer, radio, TV and communication equipment and apparatuses**	0.25	6.4	0.27	7.1	0.14	2.5
C261	Semiconductor	0.35	11.7	0.37	12.4	0.17	0.4
C262	Electronic components	0.31	2.8	0.34	2.7	0.20	3.1
C263	Computers and peripheral equipment	0.05	3.4	0.00	3.2	0.05	3.5
C264	Telecommunication and broadcasting apparatuses	0.04	3.0	0.04	3.2	0.08	2.1
C265	Electronic video and audio equipment	0.03	8.1	0.02	10.2	0.06	3.3
C266	Magnetic and optical medium	0.41	-3.2	-	-	0.41	-3.2
C27	Medical, precision, optical instruments, watches and clocks	0.07	4.8	0.05	-4.5	0.08	6.9
C28	Electrical equipment	0.10	3.1	0.10	1.9	0.10	3.9
C29	Other machinery and equipment	0.11	5.3	0.07	3.7	0.12	5.8
C30	Motor vehicles, trailer and semitrailers	0.10	7.0	0.07	8.9	0.17	3.5
C31	Other transport equipment	0.10	-1.1	0.10	-2.2	0.13	4.9
C32	Furniture	0.10	7.6	0.05	16.1	0.10	7.4
C33	Other manufacturing	0.11	8.7	0.13	13.8	0.11	8.5
C34	Repair of industrial machinery and equipment	0.02	8.5	0.06	-4.3	0.02	8.9
	Manufacturing	0.22	6.9	0.23	7.3	0.21	6.6

Second, it constructs workday equivalents monthly effective days $MED_t^{(i)}$ in each billing cycle in order to control for the calendar effects caused by mismatched intra-monthly cycles. Electricity demand varies widely between weekdays and holidays, making it inappropriate to use a predictive model simply by adding the number of days by calendar period. For example, since monthly electricity demand depends on the number of weekdays and holidays included in the month, a standard day based on electricity demand should be set to redefine the demand period. Therefore, the standard date based on electricity demand is set as the concept of the effective number of days per month and used to standardize the amount of electricity demand[5].

Third, our model is specialized to capture the effect of temperature ($TE_t^{(i)}$) on demand for electricity in cooling and heating. In order to reflect the change in electricity demand depending on the change in temperature, it is desirable to estimate the response function of continuously varying electricity demand according to the change in temperature, rather than discontinuous changes to specific temperature, such as average temperature, peak temperature, and lowest temperature[6].

On the other hand, the effect of electricity price on manufacturing production in our model is calculated using the price elasticity ($\gamma^{(i)}$) and production elasticity ($\beta_t^{(i)}$) of electricity demand as shown in (2). Subscripts are omitted to simplify the notation.

$$\frac{dlog(MIPI)}{dlog(PRC)} = \frac{dlog(y)}{dlog(PRC)} \times \frac{dlog(MIPI)}{dlog(y)} = \gamma \times \frac{1}{\beta} \quad (2)$$

3.2.2 Data and manufacturing sectors

We employ the electricity sales to manufacturing sectors in megawatt hours (MWh) from the KEPCO statistical System for the electricity demand. The real price index for industrial electricity is calculated by dividing the price index for industrial electricity by the producer price index. The Economic Statistics System of Bank of Korea provides these price indices. For the monthly industrial production index, we use the seasonal adjustment system of the trend survey of mining and manufacturing industries by Statistics Korea. Temperatures is are calculated by estimating the temperature distribution in each region using the time-specific temperature data of Seoul, Daejeon, Daegu, Gwangju and Busan, and then calculating the national temperature distribution by weighted average of the percentage of sales volume by industry. We use monthly data covering the period from January 2005 to March 2018.

The industrial classification of the KEPCO statistical System, which provides statistics on electricity sales by industry, is similar to the KSIC, but does not match in some industries. So, as shown in Table 6, we calculate the electricity sale by industry by linking the industrial

5 Section 3 of Chang et al. (2014) discusses in detail the concept, measure, and estimation of effective days.

6 See Chang et al. (2016) for a detailed discussion of measuring temperature effects and estimating response functions.

classification of KEPCO with the division level (2-digit) of the KSIC. The 10 of the 26 manufacturing sectors on the KSIC's division level are excluded from the estimation for the following reasons. C21 and C34 cannot obtain the data of electricity sold to them. The three sectors of C11, C29, and C33 are impossible to estimate due to a disconnection or instability in the time series of monthly electricity sales data. In addition, the five sectors of C12, C14, C15, C27 and C32 are not available because the coefficient of industrial production (β_i) is estimated to be negative. Therefore, the empirical analysis is conducted for only 15 sectors excluding above 10 sectors, and their production amount accounted for a high proportion of 86.4% of the total manufacturing sector based on the 2016 mining manufacturing statistics.

Table 6 Matching of electricity category and KSIC

electricity Category	Korean Standard Industry Classification	Excluded sector
Food manufacturing	C10 Food products	
Beverage production	C11 Beverage	V
Tobacco industry	C12 Tobacco	V
Fiber	C13 Textile; except clothing	
Garment fur	C14 Apparel, clothing accessories and fur articles	V
Leather shoes	C15 Tanning and dressing of leather, luggage and footwear	V
Timber tree	C16 Wood products of wood and cork; except furniture	
Pulp paper	C17 Pulp, paper and paper products	
Publishing printing	C18 Printing and reproduction of recorded media	
Oil refinery	C19 Coke, hard-coal and lignite fuel briquettes and refined petroleum products	
Chemicals	C20 Chemicals and chemical products except pharmaceuticals, medicinal chemicals	
	C21 Pharmaceuticals, medicinal chemicals and botanical products	V
Rubber plate	C22 Rubber and plastic products	
Glass	C23 Other non-metallic mineral products	
Cement		
Metal base metal		
Primary metal	C24 Basic metal products	
Assembled metal	C25 Fabricated metal products; except machinery and furniture	
Video sound	C26 Electronic components, computer, radio, TV and communication equipment and apparatuses	
Medical optics	C27 Medical, precision, optical instruments, watches and clocks	V
Electrical equipment	C28 Electrical equipment	
Other machines	C29 Other machinery and equipment	V
Car	C30 Motor vehicles, trailer and semitrailers	
Other transportation	C31 Other transport equipment	
Furniture and other	C32 Furniture	V
Office equipment	C33 Other manufacturing	V
Recycled material	C34 Repair of industrial machinery and equipment	V

3.2.3 Results of empirical analysis

The model (1) is applied to 15 manufacturing sectors and total manufacturing sectors. Table 8 shows the coefficient (b) for the real price and MAPE (Mean Absolute Percentage Error) which shows the fitness for the estimated models, two things are that this study paid attention to in the estimation results. First of all, as the MAPE shows a low 1.9% to a high 5.2%, the overall suitability of each model can be assessed as being high. The coefficients for the real prices are estimated to be statistically significant in 6 sectors of C13, C17, C20, C22, C25, and C28. However, the coefficients in the remaining sectors are statistically insignificant. For reference, production of the 6 sectors based on the 2016 mining and manufacturing statistics accounted for around 28% of the total manufacturing sectors.

Table 7 Estimation results (coefficient of electricity price, γ)

Industry	Coef. γ	t-value	MAPE(%)
C10 Food products	0.02	0.23	3.3
C13 Textiles, except clothing	**-0.31***	**-4.11**	**2.9**
C16 Wood products of wood and cork; except furniture	0.08	0.87	3.2
C17 Pulp, paper and paper products	**-0.16***	**-2.82**	**1.9**
C18 Printing and reproduction of recorded media	-0.10	-0.89	4.9
C19 Coke, hard-coal and lignite fuel briquettes and refined petroleum products	0.18	1.29	2.6
C20 Chemicals and chemical products except pharmaceuticals, medicinal chemicals	**-0.35***	**-3.8**	**2.4**
C22 Rubber and plastics products	-0.34*	-4.16	3.4
C23 Other non-metallic mineral products	-0.12	-0.92	3.9
C24 Basic metals products	-0.05	-0.41	3.4
C25 Fabricated metal products, except machinery and furniture	**-0.33***	**-2.88**	**4.0**
C26 Electronic components, computer, radio, TV and communication equipment and apparatuses	-0.19	-1.37	2.3
C28 Electrical equipment	**-0.4***	**-4.23**	**3.2**
C30 Motor vehicles, trailers and semitrailers	0.05	0.58	3.2
C31 Other transport equipment	0.02	0.06	5.2

Note: Among the estimation results of sector model (1), the real price coefficient, the corresponding t-value, MAPE is mean absolute percentage error. * Significance at 1%.

The production elasticity of the electricity price calculated by equation (2) and the power rate increase scenario (12.2% increase) is applied to finally calculate the change in production resulting from the increase in power charges due to the energy transion conversion policy as shown in Table 7. Because production coefficients are time-varying coefficients, the most recent (t=T) coefficients were applied and only those industries with significant power price coefficients were included. It was estimated that the C28 electric equipment manufacturing sector would see a 13.5% decrease in production when the power price increased by 12.2%, followed by the C25 metal processing product manufacturing industry with a 10.6% decrease in production. C17 Production reductions in the manufacturing of pulp, paper and paper products were as low as 3.2%.

4. Summary and Conclusions

This study compares the impacts of the 7th and 8th BPLE regarded as energy transition policy on electricity price, examines the 8th plan’s effects on the manufacturing sectors. As a result of the energy transition policy, electricity price is expected to increase by 12.5% and thus, the effect of each sector in manufacturing can be assessed as not to be significant in general, but it is difficult to say that the effect is small in small firms and sectors that are sensitive to electricity prices.

The effect of the energy transition policy on manufacturing depends on the change in electricity prices. According to our estimations, the increase in electricity prices is not very high, so the effect is expected to be low. However, this judgment is based on the assumption that the 8th plan will proceed smoothly as expected. In order for the energy transition policy to succeed, the government's will to pursue the policy as originally planned is important. In addition, as the effect on the manufacturing varies by firm size and sector, a policy that can minimize the negative effect through a combination of various policies will be required.

Referring to the limitations of this paper and to future research, the first is the assumption that the industrial structure of the past will continue into the future. That is, changes in operating profit margin are based on 2016 and therefore pose limitations that will not be reflected in future changes in the industrial structure. For example, in the future, technology development in manufacturing will likely take place in a way that is environmentally friendly and consumes less electricity. Given this, industry-specific electricity demand will be in a different pattern than it is today, but this is a very difficult issue to reflect in this study, leaving it as a future research task. Next, it is assumed that all increases in power generation costs are passed on to increases in electricity prices. However, it is likely not to be the case in reality. Since electricity prices directly and broadly affect consumer prices in general, it is a reality that the government cannot immediately shift changes in electricity costs to electricity prices. At the same time, it is necessary to keep in mind the justification aspect that the fuel cost should be linked.

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