Article

Sustainability of a Policy Instrument: Rethinking the Renewable Portfolio Standard in South Korea

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Abstract: The constant effectiveness of a policy instrument was a major lacuna in energy policy for a long time. However, selecting and mixing appropriate policy instruments has become crucial in the era of climate change. The aim of this paper is to investigate the renewable portfolio standard (RPS) system as a sustainable policy instrument for promoting new and renewable energy. To answer the research question, we utilized the latent growth model by applying the data on 27 types of new and renewable energy production from 2014, 2015, and 2016. Our empirical analysis concluded that the effectiveness of the RPS as a policy instrument decreased linearly each year, and its effectiveness is expected to decrease in the long term from 2017 to 2023. Profound debates and evidence from other RPS-adopting countries should be additionally conducted to bolster this theme of sustainable energy policy instruments

Keywords: policy instrument; sustainability of instrument; renewable portfolio standard; energy policy

1. Introduction

A shift toward cleaner, more ecological energy has become a critical energy policy goal [1,2] in the era of climate change [3,4]. The related concerns include how to meet this ambitious goal and what criteria should be selected as proper measures. Although the details vary depending on each nation's situation [5], many countries have adopted energy policy instruments to promote renewable energy [6–14]. In general, RPSs (nomenclature is in Appendix A) are common in the US, and feed-in tariff (FIT) countries like Germany and Spain are believed to have been successful in its implementation [15].

The feed-in tariff (FIT) and renewable portfolio standard (RPS) are two dominant policy instruments for promoting renewable energy worldwide [16,17]. Some argue that the FIT system is more effective for boosting renewable energy [18,19]. Still, others argue that the RPS prevails in its effectiveness. As shown in Table 1 below, the FIT is designed to be fundamentally voluntary and a price-based mechanism. In the FIT system, the government guarantees the adequate price of renewable electric power for enterprises. On the other hand, RPS is constructed based on the compulsory mechanism, and the government controls the quantity of renewable electric power. In the RPS system, the government guarantees the adequate quantity of electric power from renewables. The advantage of FIT is that it is low-risk. Since the government guarantees the price, no fluctuation is expected. However, in the RPS system, double fluctuation caused by the system marginal price (SMP) and renewable energy certificate (REC) may occur; nonetheless, RPS can be the more affordable option to reach the renewable energy goal by adjusting the quotas.

Table 1. Comparison of the renewable portfolio standard (RPS) and feed-in tariff (FIT) systems in South Korea.

Criteria	FIT	RPS
Instrumental mechanism	Voluntary and mixed	Compulsory
Domestic implementation	2001–2011	2012–present
System mechanism	Manipulation of price by government	Manipulation of quantity by government
	Determination of quantity (market)	Determination of price (market)
Role of government	Guarantees adequate price	Guarantees adequate quantity
Market intervention	Direct intervention in pricing	Intervention in quantity
Compensation for cost	Utilization of electric power industry basis fund	Settled by Korea Electric Power Company (KEPCO)
Amount of compensation	Determined by market	Compensated according to the quantity determined by the government and price set by the market
Unit price of compensation	Determined by government	Market makes primary decision while the government and price are set by the market
Import risk	No fluctuations	Double fluctuation (system marginal price (SMP) and renewable energy certificate (REC))
Project period	Applied to determined period (15 or 20 years)	Undetermined depending on contract
Differentiation by technology	Differentiation among standard price by source	Compensated by weighted value

Source: Jo (2017), Issues in New and Renewable Energy as Future Response to the Power Market.

South Korea is an interesting test bed for verification and fuels this competition because of the choice of instrument: a shift from FIT to RPS. Only four countries in the world—Japan, Belgium, Korea, and Italy—witnessed a complete shift in energy policy on a national scale, which is rare [20]. Apart from South Korea, countries like Japan, Belgium, and Italy will be ideal test beds for verifying the effectiveness of the energy policy instruments. The Korean government first adopted the FIT system in 2005, but then decided to change the major instrument to the RPS system in 2012 due to financial problems and poor performance in enhancing renewable generation [21]. Since the inception of the RPS system in 2012 through to the present, there has been a quantitative increase in new and renewable generation [22]. On the basis of this increase, the Korean government came to mainly rely on the RPS system, but there are still doubts about the persistent effectiveness of this instrument [23]. In the Korean RPS system, the system enforces power producers to supply a certain amount of total power generated with new and renewable energy. The obligators are power companies that have power plants generation over 500,000 kw, and designated companies are 21 companies—Korea Hydro and Nuclear Power Co., Ltd., Korea South-East Power Co., Korea Midland Power Co., Korea Western Power Co., Korea Southern Power Co., Korea East-West Power Co., Korea District Heat Corporation, Korea Water Resources Corporation, Posco Energy, SK E&S, GS EPS, GS Power, MPC Yulchon and other public enterprises and private companies—as of 2018. The designated suppliers above are implementing the new and renewable energy production to reach the set target of the RPS. The mandatory supply rate of new and renewable energy is far below (less than 80% of fulfillment) the target from 2012 to 2015 and due to the failure to comply with the target, the government charges tens of billions of won to the obligators (i.e., power companies). Moreover, the Korean government decided to revise the set target of the RPS after 2015 to reduce the gap between the target and actual implementation rate by amendment of the act on new and renewable energy. However, even after the amendment of

the act, which downsized the RPS target, the fulfillment rate did not reach the target (far below 90% of fulfillment).

The distinct perspective and added value of our study are based on two assumptions in comparison to previous studies. First, our study focuses on the aftermath of adopting the RPS system. Due to the insufficient data for an empirical methodology, previous studies that used cases, including Korea, mostly concentrated on the effectiveness of the FIT system, with very few looking at the RPS system [23]. Since the available data are now sufficient for an empirical study, our study focuses on the post-RPS time frame.

Second, our study highlights the sustainability of this policy instrument, not its instant effectiveness. Many assumptions can be made to determine the sustainability of the instrument, but in this study, we determine policy instrument sustainability as the “continuous benefits of the policy instruments in the long term.” Previous studies tended to focus on the instant outcome of renewable electricity production, comparing the before and after of the adoption of RPS. However, FIT and RPS were created ultimately to increase and promote the production of renewable energy. If the system is sustainable, the effectiveness should continuously persist or increase in the long term, and we will be able to expect constant effectiveness in that case. However, if we expect that constant effectiveness cannot be achieved in the long term, we can consider the enforcement of a policy instrument mix or other supplementary institutional prescription (such as auctions, contracts, and other financial tools) to complement the ultimate policy goal.

The sustainability of the policy instrument [24] is not a crucial issue for policymakers or scholars [19,25,26]. The reason for this underestimation is quite simple. If we think that a policy instrument is not effective, we can easily replace it with another. However, what if changing the policy instrument is not a simple task considering the external situation? What if the change in the policy instrument takes place over a longer time frame and affects other policy areas? Energy policy can certainly be such a case. Energy policy should be sensitive to the growing demands of societies [27]. With the rise of the sustainable development goal, an energy policy cannot be independent from environmental policy and social policy [28]. An energy policy becomes an extremely complicated issue because it combines public values of ecology, equity, and justice under the sustainable development goal. A change in the energy policy instrument requires an even more delicate approach. For example, Japan changed from RPS to FIT, and for this, an intense political debate and a significant modification of the original bill were undertaken during the policymaking process [29].

On the basis of these rationales, our study seeks answers by utilizing latent growth modeling (LGM), which is a renowned methodology for verifying changes over time [30]. Since our study focuses on the constant effectiveness of policy instruments, this LGM suggests an ideal standard to determine the constant effectiveness by utilizing the concept of initial value and slope. Our research question is as follows:

Q. Is the RPS system a sustainable policy instrument for promoting “new and renewable energy”?

The rest of our study is constructed as follows. Section 2 is organized into three short sections. First, we discuss the policy instrument theory and where the RPS system is situated in the macro scope of public policy theory. Second, the terminology of new and renewable energy in the Korean context is outlined to elucidate the uniqueness of renewable energy policy in Korea. The third part introduces the RPS system as a policy instrument and focuses on previous studies, including debates on the RPS and FIT and the lacuna in previous studies. Section 3 briefly introduces the data collection process and methodology. Since the latent growth model is not a common methodology in the public policy field, the logic of the model is briefly explained. Section 4 explores the results of our analysis. We discuss the model fit and the results in detail. Lastly, in Section 5, we provide a summary of our study and suggest the policy implications.

2. Theoretical Background

2.1. Policy Instrument Theory

There was a time when public policy instruments were not an important issue for scholars [31] because of their technical characteristics in the question of government. However, over the last 10 years, in-depth discussions and reflections on policy instruments and instrumentation have continued among European scholars like Halpern [31,32], Lascoumes [33], and LeGales [34], which eventually led to the development of theories on policy instruments. A policy instrument is a technical and social measure that organizes specific social relations between the public authority and its recipients in accordance with its representation [32]. Scholars also highlight the “instrumentation” (as a verb), which they define as a set of problems associated with the choice and use of tools to optimize public action. However, a terminological approach was also taken in other countries. Howlett [35,36] defines a policy instrument as a technique of governance, which includes the nation’s authority and conscious limitation. However, if we consider the term “policy instrument” from a functional viewpoint, a policy instrument can be interpreted as a means available to attain a particular outcome [37].

From a functionalist viewpoint, “public policy is fundamentally conceived as pragmatic,” and there is a need to choose instruments to solve problems [33]. Policy instruments can be found at all stages of the policy process; from agenda-setting to implementation and evaluation [38,39]. In general, a policy instrument is considered to have a larger scope than a policy tool or device, though some scholars do not pay attention to these differences [2,40]. In the light of pragmatism, a change in policy instrument affects the problem-solving capacity, which includes legitimacy, efficiency, and, most importantly, the attainment of the ultimate policy goal.

The type of instrument varies according to the type of political context and legitimacy [32]. Five types of policy instruments can be derived from this matrix: legislative and regulatory, economic and fiscal, conventional and incentive, informative and communicational, and standards for best practice. Earlier, Howlett [35,36] also suggested a spectrum of policy instruments. This spectrum contains roughly three categories of policy instrument: voluntary, mixed, and compulsory. Based on these typologies, most policy instruments like the FIT can be categorized as economic and incentive, and also voluntary and mixed, whereas the RPS corresponds to regulatory, economic, and compulsory.

Choosing the appropriate instrument is a crucial task because it can increase the possibility of meeting policy goals, though it cannot guarantee the success of a policy. There are many previous studies on policy instruments and which policy instruments can be successfully implemented under certain conditions [41,42]. However, their effectiveness and the duration of their effectiveness is another theme. Many previous studies expended their efforts in identifying the effectiveness of a policy instrument at a certain point, but what if this effectiveness does not last? Should we count on this instrument without limit because its effectiveness was once proved?

In the light of energy policy, this logical doubt must be developed in some ways. Not only South Korea, but also all countries, have a long-term view when it comes to energy policy. Energy in modern society constitutes the basis of all economic actions; moreover, policy goals like energy transition and finding appropriate energy mixes cannot be obtained in the short term. The rationale for our study, testing the sustainability of a policy instrument, relies on the importance of energy policy in the long term and the importance of responding to the climate change issue.

Thus far, countries chose certain policy instruments because of their instant effectiveness in achieving policy goals. Long-term and constant effectiveness was not the major consideration. They could simply switch the policy instrument to another option if it turned out to be malfunctional. However, for certain policy areas with a longer time frame, such as energy or the environment, the effectiveness of a policy instrument must be considered on the basis of different criteria.

2.2. The Uniqueness of Korean Terminology: New and Renewable Energy

To what extent can we call renewable energy renewable? This question has been constantly asked by concerned parties in Korean society. As a result, according to the new and renewable energy white paper published by Korea Energy Agency in 2006, the definition is as follows:

“Shin (新: new) Jaesaeng (再: Again, 生: living) Energy (New and renewable energy) is the combined word of two different energies, but it can be used as Shin Jaesaeng Energy in a single word.”

This official definition was criticized by Korean intellectuals and civil organizations and has raised questions about the relevance of new and renewable energy. Prior to 2008, the Korean government did not recognize the importance of the notion of renewable energy even though civil society had repeatedly raised the issue. Then, green growth became President Lee Myung-bak’s political paradigm (2008–2012) and was the trigger for change. The Ministry of Trade, Industry and Energy finally corrected the definition in January 2009 via the Energy Roadmap. During the former government, the concept of renewable and new energy had been improved, but compared to the international standard, problems still needed to be solved.

Table 2 shows the different conceptual categories of renewable energy resources per country. In general, European countries admit to the narrow scope of renewable resources, while the South Korean government includes the largest number of new and renewable energy resources in single frontiers. As shown in Table 2 below, the South Korean government labels many more sources as new and renewable energy than other countries do. South Korea is the only country that gives the “renewable” label to new sources such as liquefied coal and liquefied heavy oil. For fuel cells, two questions arise: First, can we consider fuel cells as a renewable source such as wind and solar? Second, is it appropriate to categorize fuel cells as a “source,” when in reality they provide storage? The Japanese government used the new energy in the same context, but it separated new energies from renewable energies and began to regulate and promote them via different laws. Korea does not only consider new energy as renewable energy, but also determines waste in a broader sense than other countries.

Table 2. Conceptual categories of renewable energy.

Source	International Energy Agency	EU	Germany	France	US	Japan	Korea
Solar photovoltaic (PV)	○	○	○	○	○	○	○
Solar thermal	○	○	○	○	○	○	○
Wind	○	○	○	○	○	○	○
Hydro	○	○	○	○	△	○	○
Geothermal	△	○	○	○	△	○	△
Biomass	○	○	○	○	○	○	○
Waste	△	△		△	△	△	○
Landfill gas		○	○	○	△		○
Marine	○	○		○	△		○
Hydrogen						○	○
Fuel cells						○	○
Liquid carbon							○
Petroleum residuum							○
Other residuals							○

Source: Lee (2017), unpublished dissertation by Youhyun Lee, University of Paris 1, Pantheon-Sorbonne. △: Partially admitted by the government (can be excluded in national statistics), ○: Fully admitted by the government (included in national statistics).

Because of this unique categorization, the RPS system in South Korea also offers the same benefits to new energy sources such as hydrogen, fuel cells, etc. Thus, it is mandatory to include all kinds of renewable and new energy suggested by Korean law in the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy. Twenty-seven kinds of new and renewable energy

have been counted as new and renewable energy generation by the Korean Energy Agency [43]. As of 2018, solar thermal, solar photovoltaic (PV), hydro, wind, bioenergy, refuse derived fuel (RDF), power generation turning waste into gas, tidal currents, fuel cells, geothermal, waste, landfill gas, byproduct gas, and integrated combined cycle (IGCC) are the new and renewable energy sources that can be supported by the RPS system under the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy.

2.3. Previous Studies: Debates on RPS and FIT—RPS as an Effective Instrument?

A change in policy instrument from the FIT to RPS took place in 2012 (the law was promulgated in 2010, but the government needed a preparatory period from 2010 to 2012). The adoption of a new policy instrument or new policy program means the abandonment of an old one [44]. There were two core reasons for abandoning the FIT system in South Korea: a budget issue and the need for renewable energy growth [45]. The FIT system caused a profit imbalance during the implementation period. The Electric Power Industry Basis Fund was founded to subsidize the gap between the FIT base price and the wholesale power price. However, the domestic power pricing system was not efficient, and this put an economic burden on the Electric Power Industry Basis Fund. Another reason was the desire to promote the efficient growth of the renewable energy industry and its production size [46]. The proportion of new and renewable energy in terms of overall primary energy in the FIT implementation period grew by 1.64%, from 1.1% to 2.74% [47]; this result was not sufficient compared to major countries like Germany, Japan, and Northern European countries.

The FIT and RPS are the most far-reaching and popular policy instruments used in the world [45,48]. Debates on the efficiency of these two instruments are still ongoing, with many of them taking place in RPS implementing countries like the US, UK, Canada, Japan, Italy and Korea as shown in Table 3 above. This conflict has always been an interesting issue for scholars [49].

Table 3. Implementation of RPS per country.

Country	RPS Legislation	Penalty	Fulfilment Rate	Quota (% , Year)	Note
US	1983–present	50–70 USD	91% (2007)	10%–30% (2020)	Can replace RPS quota with energy efficiency program
Japan	2003	-	100% (2006)	-	Differentiated quota for each producer
UK	2002	30 UK pounds	63% (2007)	15.4% (2015)	
Italy	1999	1.5 times the REC price	-	17% (2020)	Applies FIT to solar energy
South Korea	2010	Unfulfillment rate*REC price	60–70%	8% (2020)	

Source: Park (2018), Designing a better Korean RPS.

Previous studies highlighted the effectiveness of the FIT system for promoting renewable energy [50]. The FIT can be an effective instrument for encouraging investment, especially in small renewable enterprises [51]. Scholars also insist that the FIT system is effective in enlarging the renewable market and ultimately creating an environment suitable for expanding the use of renewables [52].

On the other side, the effectiveness of the RPS system is discussed in several studies [38,53–55]. The RPS is a relatively new instrument for promoting renewable energy [40]. Over the last 20 years, many states in the US adopted an RPS system; also, the UK is famous for its own quotas system called renewable obligation. As a result, scholars who exclusively study RPS systems usually choose the US or UK because of its abundant sample size. Earlier, Menz [53] used empirical models to evaluate the effectiveness of renewable policy instruments, but only in the wind energy sector. Carley [55] also evaluated the effectiveness of RPS implementation with data from the US. Fischlein and Smith [56]

showed that the RPS is an effective instrument, but this study also suggested that the various forms of policy design play a crucial role in the effectiveness of the RPS system.

Recent studies presented empirical evidence of the effectiveness of the RPS by using data from after 2012, when the Korean government changed its policy instrument from the FIT to RPS. With a few exceptions [15,20], even Korean scholars did not pay attention to this situation due to the lack of data. However, recent studies have tended to place more focus on the Korean situation. Kim, Kim, and Park [21] analyzed the effect of the RPS. They used 10-year data from 2005 to 2014 to analyze new and renewable energy generation in 16 cities and provinces of South Korea. Their study showed that the RPS had positive effects on increasing the generated outputs of new renewable energy, which empirically confirmed that, based on its legal force, the RPS was effective in increasing the actual generated outputs of new renewable energy. Their research showed that the RPS system was more effective for promoting new and renewable energy production than was the previous FIT system before 2012.

Lim and Jo [57] compared the effectiveness of the FIT and RPS using annual data from 104 countries including South Korea from 1999 to 2014. Their study fueled the old debate of FIT vs. RPS. For OECD (Organization for Economic Co-operation and Development) countries, the effect of FIT policy was greater than that of the RPS. However, for non-OECD countries, the RPS was more effective than the FIT. In the case of South Korea, the FIT system was more effective than the RPS system. The biggest lacuna in their study was in their data collection. The Korean government changed its major policy instrument for promoting renewables in 2012, from the FIT to RPS. In addition, usually in policy evaluation we do not include the results from the adoption year, because it is not appropriate to judge the real effectiveness of a policy instrument that soon [58,59]. Since they used data up to 2014, their data cannot be regarded as sufficient for evaluating the RPS system.

Based on our examinations of previous studies, which mainly concentrated on the FIT system, our study emphasizes the aftermath of the RPS system. In addition, unlike previous studies that mostly highlighted the instant effectiveness of RPS or FIT, our study aims to evaluate the constant effectiveness of a policy instrument—sustainability of the RPS system.

3. Data and Methodology: Latent Growth Model

To examine our research question, “Is the RPS system a sustainable policy instrument for promoting new and renewable energy?” we utilized data from the Korea Energy Agency, which is affiliated with the Korean Ministry of Trade, Industry and Energy. In our study, we tried to utilize the most recent data from 2014, 2015, and 2016 to evaluate the continuous effectiveness (sustainability) of the RPS system in attaining the policy goal during its actual implementation.

This study focuses on analyzing the increase in electricity generated by each new and renewable energy source. Therefore, the sample represents new and renewable energy sources. The same is included for all data from 2014, 2015, and 2016. Each year is an observation variable. That is, the target of analysis is the energy source and the year is the observation variable. It does not include renewable energy electricity production from the planning stage since it covers only the newly added (not cumulative) capacity from each year. We collected data from the government report “White Paper on New and Renewable Energy” which is published by the Korea Energy Agency biannually.

To evaluate the concrete effectiveness of public policy, scholars sometimes modify their data's time frame [59,60], eliminate potential confounding factors, and exclude data from the year before implementation. Eliminating the time lag is sometimes considered as an exact measure to verify the actual policy outcomes [58]. Moore and Rhodes [58] suggested that a time lag of two years or more can be expected to verify the consequences of a policy. This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn. Table 4 below shows the sample size and unit of analysis of our study, and more details are in Appendix B.

Table 4. Sample size and data.

Sample	Definition	Data
2014	Electric power production by new and renewable energy generation in 2014	Sum of new and renewable energy generation per new and renewable energy resource in 2014
2015	Electric power production by new and renewable energy generation in 2015	Sum of new and renewable energy Generation per new and renewable energy resource in 2015
2016	Electric power production by new and renewable energy generation in 2016	Sum of new and renewable energy Generation per new and renewable energy resource in 2016
27 units of new and renewable energy resources used in analysis		

Solar thermal, solar PV, hydro, wind, marine, hydrothermal, biogas, bio diesel, woodchips, briquettes, bio SRF(Solid Refuse Fuel),, wooden fuel, wood pallets, used wood, black liquor, sewage sludge, refuse-derived fuel (RDF), power generation turning waste into gas, fuel cells, geothermal, industrial waste, ciment killen, bio heavy oil, used gas, landfill gas, byproduct gas, and integrated combined cycle (IGCC).

In this study, we used latent growth modeling (LGM) to analyze the sustainability of the effect of the given policy instrument. LGM is a popular methodology for analyzing longitudinal data [61]. It has emerged as a flexible analytic technique for modeling change over time because it can describe developmental processes at the inter- and intra-individual levels [62]. This research utilizes LGM as an analytical tool in the evaluation of a policy instrument. LGM techniques capitalize on individual variability and simultaneously focus on correlations over time, changes in variance, and shifts in mean values [63]. Policy evaluation research using LGM was applied to analyze growth in an academic and educational policy program for children [64]. In LGM, given a difference in initial status and growth, the longitudinal effects of a policy or program can be confirmed. Most of the previous studies, especially in the policy evaluation field, concentrated on a certain point in the adoption of a policy instrument to evaluate the effectiveness of the instrument. However, our study investigates the sustainable instrumental effect over time. This continuous approach helps us understand the dynamic nature of the policy instrument's effect.

It is important to verify whether the policy instrument in question displays a consistent performance. The effectiveness of policy instruments should be assessed scientifically, and through this assessment, we can evaluate the public policy, which is intrinsically related to the proper use of the national budget. LGM is a method used to evaluate the sustainability of a performance in the fields of psychology, sociology, education, and public administration [65]. It was designed to capture the overall changes in the observed variables, which are measured periodically [66]. Factors should be fixed in advance, so that each factor shows a specific temporal change [67]. Then, the mean value of the factors should be estimated. LGM has been frequently used to evaluate and estimate the aftermath of project implementation.

This methodology is also useful for evaluating ongoing projects related to technology and agriculture. For example, research on how agricultural productivity changed after China joined the WTO (World Trade Organization) was undertaken using LGM. In this study, membership of the WTO can be considered as the instrumental change [68]. LGM is an appropriate method for evaluating public policy with a long-term time frame, which includes the obvious change of policy. Based on the previous studies, LGM is a suitable method to analyze how effectiveness of an instrument changes after the adoption.

LGM was developed by McArdle and Epstein in 1987 [63]. It is a relatively recent methodology that is suitable for longitudinal studies. LGM is a special form of structural equation modeling, which has been frequently used in social science [69]. In LGM, the key components are the latent variable and the observed variable [70]. A latent variable is a variable that cannot be observed or measured directly. For example, intelligence measured with an IQ(Intelligence Quotient) test would be

an appropriate sample. Everybody has a certain intelligence capacity, but it is extremely difficult to measure or define it in detail. Unlike height or feet size, intelligence has invisible and unmeasurable features. However, a researcher can estimate intelligence indirectly using questions (on the observed variable). In LGM, the latent variables correspond to the slope and initial status, and the observed variables are longitudinal data that were observed each time. The latent variables and observed variables are explained in Figure 1. In our study, X1 signifies the year 2014, and X2 indicates 2015.

The slope can be interpreted as the degree of change of the average value through the time processing, which ultimately implies the variation rate of each sample. The initial value implies the initial state (intercept: initial value) of each sample, which indicates the mean of the variable at the time of observation. The LGM measures the growth curve over a certain period of time and determines the initial intercept and slope of the average growth curve (Figure 1).

Figure 1. Latent growth model.

To determine the sustainability of the RPS system, we focused on the slope of electric power generation per year. In addition, we selected the years 2014, 2015, and 2016 because this period was suitable for evaluating the net effectiveness of the RPS system, and the utilization of LGM on at least three points in time should be observed. The Korean government discussed the re-adoption of a partial FIT system in 2017 and re-adopted a partial FIT system for solar PV starting in 2018 [22]. Therefore, the years 2014, 2015, and 2016 could be ideal for a less biased testing of the effectiveness of the RPS policy instrument.

In the Box 1 below, we revisit the conceptual definition of sustainability of policy instruments. In addition, we suggest the operational definition of sustainability of policy instruments based on the latent growth model, and set two conditions when the sustainability of policy instruments can be obtained: the initial value is statistically significant and in a positive direction (+) and the slope is not statistically significant, or the slope is in a positive (+) direction, regardless of the statistical significance of the initial value.

Box 1. Sustainability of policy instrument (RPS).

- (1) **Conceptual definition:** The continuous benefits of the policy instrument in the long term (at least 3 years or more)
- (2) **Operational definition:** Initial value is statistically significant and in a positive (+) direction and the slope is not statistically significant or The slope is in a positive (+) direction, regardless of the statistical significance of the initial value

Descriptive statistics are listed in Table 5. The units are kilowatts (kW) for the raw data on the newly added electricity generation and ln for the natural log value. The standard deviations were relatively high compared to the average. In addition, the N value was 27 in total.

Table 5. Descriptive statistics.

	Sort	N	Minimum	Maximum	Mean	Std. Deviation
kW	2014 (newly added capacity)	27	0	926,264.0	77,991.7	188,763.4
	2015 (newly added capacity)	27	0	1,133,900.2	78,784.6	227,634.2
	2016 (newly added capacity)	27	0	909,217.8	63,103.6	177,529.9
ln	2014 (newly added capacity)	27	0	13.74	6.8802	5.16984
	2015 (newly added capacity)	27	0	13.94	5.7766	5.16558
	2016 (newly added capacity)	27	0	13.72	5.3942	5.44168

Muthen and Muthen [71] used the Monte Carlo method with a minimum verification level of 40, and Hamilton et al. [72] analyzed with a minimum of 25 samples. In particular, Hamilton et al. [72] found that convergence, model fit, and proportional variability were better when the number of samples was over 25. However, even in 25 cases, there was no effect on the parameter bias and standard error. On the basis of these results, we utilized the annual data for our study. When such a small sample number is to be utilized, an unconditional model must be used, rather than a conditional model.

The natural log [73] was used as the analysis data. In 2014, the new supply capacity was found to be at least 13.74 with a minimum of 0. In 2015, the new supply capacity was confirmed to be at least 13.94 with a minimum of 0. In 2016, the new supply capacity was confirmed to be a maximum of 13.72 and a minimum of 0. The annual minimums were all the same, and the differences between the maximum values were not large. As a result, the data categories were considerably improved. However, a normality test seemed to be necessary because of the high standard deviation value.

In this study, a Kolmogorov–Smirnov test was performed as there were fewer than 30 data points and the difference between the mean and the variance was not large. Normalization tests were performed on the basis of natural logarithm values. According to the results, the three-year data showed statistical significance ($p < 0.001$). The data confirmed its utility on the basis of its scale and the fulfillment of the minimum regularity standard (see Table 6).

Table 6. Tests of normality.

	Sort	Kolmogorov–Smirnova			Shapiro–Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
ln	2014 (newly added capacity)	0.242	27	0.000	0.801	27	0.000
	2015 (newly added capacity)	0.276	27	0.000	0.821	27	0.000
	2016 (newly added capacity)	0.321	27	0.000	0.762	27	0.000

4. Results

4.1. Verification of the Model

There is no consensus on which fitness index is best for evaluating the overall fit of a model [74]. In general, three indices are used to determine the fitness of a path model as shown in Table 7. Specifically, an absolute fit index is used to evaluate the overall fit of the model. In order to compare the fit of the model constructed by the researcher against a basic model (independent model), an incremental fit index is used. Finally, the parsimonious fit index is checked to evaluate the degree of conciseness

of the model. However, these three indices also include various indicators, which makes it difficult for researchers to evaluate the fitness of the actual path model. This study employed the following fit indices: the χ^2 test, the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the normed fit index (NFI), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the incremental fit index (IFI).

Table 7. Fit index and determination of latent growth model.

	χ^2	<i>p</i> -Value	NFI	TLI	CFI	RMSEA
Index Score	0.356	0.949	0.99	1.078	1.00	0.000
Criteria for Determination	-	$p \geq 0.1$	Good if more than 0.9	Good if more than 0.9	Good if more than 0.9	Good if less than 0.1

NFI, normed fit index; TLI, tucker lewis index; CFI, comparative fit index; RMSEA, root mean square error of approximation.

Due to the strictness of the null hypothesis and sensitivity to the sample size in the χ^2 test, it is recommended to refer to various indicators. Therefore, we could not rely on the unique χ^2 test to determine the fitness of the path model, and it is highly recommended to use another fit index [75].

When the *p*-value is significantly less than 0.05 in the χ^2 test, a difference can result between the sample covariance matrix and the fit covariance matrix because of a violation of the multivariate normality assumption or a sampling error. However, if the sample size is large, the statistical power increases in proportion to the number of data points, which can eventually cause the value of χ^2 to be significant.

Therefore, even if the value of χ^2 is calculated to be large, the constructed path model may be a good model to fit the data. Therefore, the fitness of the model should be finally determined through other fitness indices [76]. However, there is still an ongoing debate among researchers over what model fits should be commonly applied.

For this reason, Shim [77] discussed the common compliance index centering on major scholars for the sake of developing and correcting SEM. Mueller [78] and Fan et al. [79] have suggested that the three most common indicators should be the RMSEA, NFI (= TLI, Tucker Lewis Index), and CFI, as the most commonly used indicators [70,80–82]. Our study also included the RMSEA, NFI (= TLI), and CFI to support this viewpoint, and we applied the NFI and χ^2 validation as well. The TLI and IFI are both indices developed from the NFI. These indices are larger than 0 and can sometimes be larger than 1.

The χ^2 for verifying the overall fitness was 0.356 and the *p* value was 0.949, which was statistically insignificant. In addition, the NFI, TLI, and CFI were larger than 0.9, which means that the model fit was good. On the basis of these results, we judged that our model was appropriate for analysis.

4.2. Results of the Analysis

Table 8 shows the slope and initial value. The initial value of the mean and the slope had statistical significance. The initial value of new and renewable energy in 2014 was significant. In addition, we confirmed that the change in electricity production from 2014 to 2016 had a significant effect on the slope. In contrast, the initial values and slopes of variance were not statistically significant. The variance of the initial value signified the distribution level of the individual production based on the average of the electricity production by each energy source measured in 2014. This implies that the initial values of individuals did have homogeneous characteristics.

Table 8. Slope and initial value.

	Latent Growth Model			
	Average		Variance	
	Estimation	Standard Error	Estimation	Standard Error
Initial Value	7.503 ***	1.17	16.161	11.248
Slope	−0.743 *	0.415	0.305	1.694

* $p < 0.1$, *** $p < 0.001$.

In other words, the characteristics of the new and renewable energy sources do not represent various values; therefore, it can be judged that the characteristics of the initial values can be evaluated only by the average value. Thus, the present result can be understood as the difference in change without further considering other factors affecting the individual energy sources.

The average estimation of i^{th} log (electricity generation) = $7.503 - 0.743 \times (i)$, ($i = 1, 2 \dots, n$)

These results can be interpreted as follows (see Table 9). The first year of electricity generation in 2014 was not 0, and over subsequent years it was confirmed that electricity generation decreased by 0.743 per year on average. In this case, since the value was the sum of the natural logarithm of the electricity generation amount, each result can be presented by the exponentiation of the yearly average estimation value.

Table 9. Estimation of log (electricity generation) per year.

	2014	2015	2016
Estimation	6.76	6.017	5.274
Electricity Generation (kW)	862.6 [= exp (6.76)]	410.3 [= exp (6.017)]	195.2 [= exp (5.274)]

The result of the yearly estimation and the result converted by electricity generation are shown in Figure 2. The results of the analysis showed that the estimated value decreased linearly, and we can conclude that the converted value also decreased with the rate. In the long term, the sustainability of electricity production is expected to continue to decrease.

We can logically conclude that the policy instrument was effective in the post-2012 period—the implementation period of the RPS. The initial value was significant, which reflects its instant effectiveness. However, the results of the analysis suggested that this positive effect is not maintaining its effectiveness in an equal fashion. In addition, the reduction level is decreasing year by year. This can be observed in the declining slope of Figure 2 below. If this trend continues, the present system will not have a positive effect on renewable electricity production from 2023 on as shown in Figure 3. Hence, the sustainable effect of renewable energy on electricity production will decrease rapidly in the long-term.

Figure 2. Annual estimation of result and change in electricity generation.

Figure 3. Sustainability of renewable energy electricity generation for long-term estimation.

5. Discussion and Concluding Remarks

The aim of our study was to evaluate the RPS system as a sustainable policy instrument for promoting new and renewable energy. For our analysis, we used 27 kinds of new and renewable energy production from the years 2014, 2015, and 2016, and utilized LGM. As a result, in contrast to some previous studies and government documents, our analysis showed that the effectiveness of the RPS as a policy instrument decreased linearly, and this is expected to continue in the long term. Based on our result, the RPS system in South Korea, which was designed to promote new and renewable energy production, cannot be considered as a sustainable policy instrument in the long term.

Our study has some limitations caused by the uniqueness of renewable energy's classification, which combines renewable and new energies into a single policy area. As shown in Table 2, the conceptual frontiers of admitted renewable energy sources vary country by country. To the best of our knowledge, the South Korean government utilizes the largest number of categories of renewable energy resources, which combines new energy such as hydrogen, IGCC, and residual fuels. However, the Korean case still offers some policy implications in a different way. The new energies mentioned above cannot be the best solution to finding an alternative to conventional energy, but they are considered to be the second-best plan to reduce greenhouse gases and achieve an energy transition. For developing countries, an extension of the RPS or FIT will be needed to provide alternative energy. In that case, our research could provide some takeaways and insights for designing their policy instrument mix.

Despite its limitations, our study provides theoretical and empirical implications. First, our study extended the research scope by concentrating on the aftermath of the RPS system, which previous studies did not approach because of a lack of data. Second, we tried to measure and predict the sustainability of a policy instrument, while previous studies were mostly concerned with the instant effectiveness of the RPS system.

Based on previous studies, RPS indeed solved the pending issue of energy. First, the change from FIT to RPS decreased the financial burden on the government [20]. Second, if we analyze the size of renewable sources, the effectiveness of RPS seems positive. For example, Kwon's [23] research emphasized the fast growth of biomass and solar PV. If our research scope was limited to the major renewable sources, like solar PV, wind, and biomass, the result would have been different from the present one. Hence, we are not denying the effectiveness of the RPS, but we are skeptical about its constant effectiveness as a major policy instrument for encouraging new and renewable energy and fighting climate change. To date, the sustainability of policy instruments has not been a crucial issue for practitioners and scholars in the public policy field. However, policies related to environment and energy have a longer implementation time frame [83] than other disciplines. In other words, the choice and change of a policy instrument cannot be easily or quickly done. As a result, the prudence of adopting [84] and mixing policy instruments [45] requires more deliberation and reflection from a wider and longer viewpoint.

The results of our analysis support the recent decision by the Korean government to partially reintroduce the FIT system for small enterprises providing solar PV [22]. Although the proportion is comparatively low, this attempt at mixing policy instruments could enhance the net advantage of policy instruments and improve the sustainable effectiveness to help achieve policy goals. Additionally, we recommend considering a mix of the RPS and auctions [45], which could eventually lead to a more balanced [85] and risk mitigating design.

The area of energy policy now concerns the environment because of the issue of climate change. The role of scholars and practitioners in the energy field is to find the most appropriate instrument to achieve the two competing values of boosting the economy and protecting the environment. The importance of selecting a policy instrument or mixing instruments will increase [45,86]. More debates and research should be conducted to arouse interest in the theme of sustainable energy policy instruments. Also, further research in other countries that have adopted the RPS will be needed to confirm the inter-subjectivity of the results of our analysis.

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Appendix A. Nomenclature of the Study

Abbreviation	Stand for
RPS	Renewable Portfolio Standard
FIT	Feed-in Tariff
PV	Photovoltaic
LGM	Latent Growth Model
SMP	System Marginal Price
REC	Renewable Energy Certificate
IGCC	Integrated Gas Combined Cycle
KEPCO	Korea Electric Power Company

Appendix B. The Production of Electricity by Type of New and Renewable Resources

Year		2017	2018	2019	2020	2021	2022	2023
Estimation Energy		92.85	44.17	21.01	9.99	4.75	2.26	1.08
Per source	percentage							
Solar thermal	6%	5.54	2.63	1.25	0.60	0.28	0.13	0.06
Solar PV	8%	7.42	3.53	1.68	0.80	0.38	0.18	0.09
Wind	7%	6.34	3.02	1.43	0.68	0.32	0.15	0.07
Hydro	5%	4.90	2.33	1.11	0.53	0.25	0.12	0.06
Marine	0%	0	0	0	0	0	0	0
Geothermal	7%	6.37	3.03	1.44	0.69	0.33	0.16	0.07
Hydrothermal	6%	5.80	2.76	1.31	0.62	0.30	0.14	0.07
Biogas	5%	4.75	2.26	1.07	0.51	0.24	0.12	0.05
Landfill gas	3%	2.68	1.27	0.61	0.29	0.14	0.07	0.03
Bio diesel	0%	0	0	0	0	0	0	0
Wood chip	5%	4.63	2.20	1.05	0.50	0.24	0.11	0.05
Briquettes	0%	0	0	0	0	0	0	0
Wooden fuel	0%	0	0	0	0	0	0	0
Wood pallet	6%	5.46	2.60	1.24	0.59	0.28	0.13	0.06
Used wood	0%	0	0	0	0	0	0	0
Black liquor	0%	0	0	0	0	0	0	0
Sewage sludge	0%	0	0	0	0	0	0	0
Bio-SRF	6%	5.84	2.78	1.32	0.63	0.30	0.14	0.07
Bio heavy oil	4%	3.79	1.80	0.86	0.41	0.19	0.09	0.04
Used gas	4%	4.05	1.92	0.92	0.44	0.21	0.10	0.05
Industrial waste	5%	4.52	2.15	1.02	0.49	0.23	0.11	0.05
Turning waste into gas	5%	4.46	2.12	1.01	0.48	0.23	0.11	0.05
Ciment killen	2%	1.71	0.81	0.39	0.18	0.09	0.04	0.02
SRF	5%	5.02	2.39	1.14	0.54	0.26	0.12	0.06
Byproduct gas	2%	1.91	0.91	0.43	0.21	0.10	0.05	0.02
Fuel cells	6%	5.38	2.56	1.22	0.58	0.28	0.13	0.06
IGCC	2%	2.30	1.10	0.52	0.25	0.12	0.06	0.03

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