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RPS and FIT with Transaction Costs*

Sunghee Shim[1)]** · Kyonghwa Jeong[2)]***

수입중간재와 신재생에너지정책

심성희[1)]** · 정경화[2)]***

1)에너지경제연구원(Korea Energy Economics Institute)
2)목포대학교(Mokpo National University)

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국 문 요 약

우리나라는 2002년부터 시행해온 FIT를 대신하여 2012년부터 RPS로 신재생에너지 정책을 전환하였다. RPS와 FIT는 국내 신재생에너지의 보급 확대 및 기술개발을 촉진하기 위해 도입되었다. 우리는 신재생에너지정책수단(RPS와 FIT)이 관련 기업들의 중간재 선택에 미치는 영향을 분석하였다. 기업들이 선택할 수 있는 중간재는 국내재와 비용경쟁력이 있으나 거래비용이 존재하는 수입재를 고려하였다. 거래비용이 크지 않을 경우에는 RPS가 초기 시장경쟁력이 낮은 국내 신재생에너지 생산업자에게 유리한 환경을 조성하여 해외 신재생에너지기업과 경쟁할 수 있는 여건을 조성할 수 있는 것으로 분석되었다. 이것은 시장경쟁력을 갖춘 해외 기업과 비교하여 상대적으로 비용 경쟁력이 낮은 국내 녹색에너지산업을 고려하면 RPS가 한국정부의 최적의 선택임을 함축한다.

주제어 RPS, FIT, 거래비용, 신재생에너지, 기술개발

Abstract

In 2012, Korea adopted RPS after having implemented FIT for 10 years since 2002. We show how the choice of policy between RPS and FIT affects firm's choice of intermediate goods between a domestic and a foreign supplier, given the presence of transaction costs, When transaction costs are not sufficiently high, RPS is found to create a favorable environment for the domestic provider, which has comparative disadvantage initially, to be able to enter the market and to catch up with the foreign provider. The result implies that the Korean government's decision to implement RPS was optimal, given Korea's comparative disadvantage in green energy relative to major developed countries.

Keywords RPS, FIT, Transaction Cost, Renewable Energy, R&D

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** 제1저자 : hsims@keei.re.kr
*** 교신저자: jeongkyo@mokpo.ac.kr

Ⅰ. Introduction

Because the rise of climate change is an important global issue, most countries are turning their attention to the renewable energy industry. It is believed that the promotion of renewable energy not only improves environmental integrity but also enhances energy security and opens new windows of opportunity for domestic economic development and job creation by strengthening relevant industrial capacities (Berry and Jaccard, 2001; Komor and Bazilian, 2005; Lipp, 2007). However, because renewable energy is still not cost competitive relative to fossil fuels, countries are implementing various policies and measures to foster and disseminate renewable energy. In particular, both the Feed-in Tariff (hereafter, FIT) and the Renewable Portfolio Standard (hereafter, RPS) are prominent policy proposals.

Because the two policies differ in the methods and structures by which they support renewable energy, the choice between FIT and RPS involves trade-offs.1) In general, the existing literature finds that FIT is more effective in stimulating investment in various renewable energy sources, while RPS is a more cost-effective way of encouraging competition to reduce costs (Menanteau et al, 2001; Lipp, 2007). Nonetheless, very few studies have addressed the issue of which policy is more appropriate in fostering the development of domestic renewable energy capacity, which is one of the important objectives of renewable energy policy.

Indeed, which policy choice would lead to more effective development of domestic renewable energy capacity remains unclear. Theoretically, FIT may be better from the perspective of strengthening domestic renewable energy capacity, as FIT more effectively promotes various renewable energy sources. However, the experience of Korea shows that FIT is not necessarily the optimal choice for the promotion of renewable energy capacity using domestic technology.2) Korea, a late mover in the renewable energy industry, adopted FIT in 2002 as a core measure for accelerating the deployment of renewable energy. The

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1) For a discussion of the pros and cons of price and quantity controls in promoting renewable energy, see Lipp (2007), Menanteau et al. (2003), Mitchell et al. (2006), Tamas et al. (2010), Kim, H. and Kim, Y. (2009)

2) FIT became more controversial, however, in late 2011 just before the start of RPS in Korea, as the Japanese House of Councilors passed the Bill on Special Measures Concerning Procurement of Renewable Energy Sourced Electricity by Electric Utilities, switching its policy from RPS to FIT starting on July 1, 2012.

Korean government gave careful consideration to RPS after 2-3 years of implementation of FIT, which required significant funding from the special energy fund program. After ten years of FIT and RPS, the promotion of renewable energy has been unsuccessful due to cost disadvantages relative to traditional fossil fuels. Renewable energy production in Korea has increased relative to primary energy production, from 1.51% in 2003 to 2.40% in 2011 (KEEI, 2012). Furthermore, the fact that a different weight for 1 unit of renewable energy credits (REC) based on renewable energy sources causes inequality between renewable energy sources and distorts renewable energy incentives has been a point of controversy since the start of RPS. Additionally, it is not entirely clear whether RPS is more effective in the development of domestic renewable energy technology than FIT. Most renewable energy utilities in Korea were installed with foreign renewable energy generation equipment —from Japan and Germany in the early years and from China in later years—due to the early stage of domestic technology development and price competitiveness in the renewable energy industry.

Employing a game-theoretic industrial organization model, the present paper examines whether FIT or RPS contributes more to the development of domestic renewable energy capabilities. In particular, we focus on the role of transaction costs for imported goods when assessing the choice between the two policy measures. ‘Transaction costs’ refers to costs incurred when renewable energy equipment is imported from a foreign provider rather than purchased from a domestic provider. For example, transaction costs may be the difference in maintenance costs between domestic and foreign equipment, import duties, or the transportation costs of importing equipment. It is well known that transaction costs, such as utility fees for engineering reviews and inspection, may be unnecessarily high (Mendonca, 2007). This paper shows that when transaction costs fall within a reasonable range, RPS is a better choice than FIT for the promotion of the domestic renewable energy equipment industry. RPS outperforms FIT because domestic equipment providers find opportunities to enter the market under RPS in the presence of transaction costs of foreign equipment. Furthermore, we find that social welfare, as the sum of consumer and producer surplus, under RPS is higher than under FIT in the moderate range of transaction costs.

The paper is organized as follows. In sections 2 and 3, the structure and outcomes of the model are discussed. Section 4 addresses how FIT and RPS influence social welfare. Policy implications, the limitations of this study, and possible future challenges are briefly discussed in section 5.

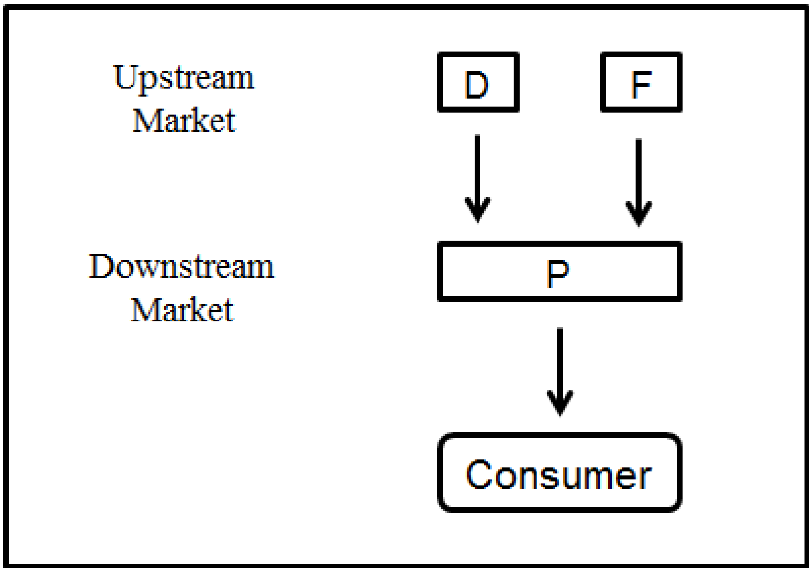
Ⅱ. model

Consider a vertically integrated market, where upstream firms provide intermediate goods to downstream firms. Two players produce renewable energy-generating equipment in the upstream market: a domestic renewable energy technology provider (D) and a foreign renewable energy technology provider (F). In the downstream market, a renewable energy power generator (P) competes on price against conventional fossil fuel generators (C).

The renewable energy power generator produces the same quality of electricity as conventional power generators but faces different marginal production costs. Specifically, we assume that the marginal production cost of renewable energy electricity is higher than that of fossil fuel generators. Prior to government intervention in the form of RPS or FIT, the renewable energy power generator cannot supply electricity to the market due to its high marginal cost relative to that of fossil fuel generators. Indeed, it is well known that the costs of renewable energy are much higher than those of conventional fuels. Renewable energy projects are typically smaller and may require additional time and information for financing, owing to uncertainties regarding renewable energy performance (Mendonca, 2007). With the introduction of RPS or FIT, however, renewable energy power generators can participate in the electricity market.

The renewable energy power generator purchases one unit of renewable energy-generating equipment from either the domestic renewable energy technology provider or the foreign renewable energy technology provider, who compete against each other to sell renewable energy-generating equipment to the renewable energy power generator. Let us assume that, for the domestic renewable energy technology provider to enter the market, it must invest a fixed amount K_1. The sunk cost K_1 includes an upfront cost for the construction of production equipment and an initial R&D cost. We assume that the foreign provider is the present incumbent and participates in the international market; thus, it does not incur any sunk costs.

Figure 1. Vertical Market Structure for Renewable Energy Electricity



The domestic provider has a comparative cost disadvantage relative to the foreign provider in that the marginal cost of D is higher than the marginal cost of F. For simplicity, we also assume, without loss of generality, that the marginal costs of renewable energy power generators and of fossil fuel generators, other than the purchasing cost of renewable energy-generating equipment, are normalized to zero.

To purchase the equipment from F rather than D, the renewable energy power generator incurs an additional cost of δ, which reflects a tariff charge, transportation costs, maintenance costs and the costs of engineering reviews and inspections of imported equipment.

The government seeks to accelerate the deployment of renewable energy at a given level; to achieve this, it can choose between FIT and RPS. If RPS is selected, the government will set the minimum amount of renewable energy electricity as a proportion of total electricity, $\bar{q}=\alpha\bar{Q}$, where $\bar{Q}$ is total electricity consumed, and α is the ratio of electricity produced by the renewable energy resource. Total consumer demand for electricity in the second and third stages is assumed to be fixed at $\bar{Q}$. If FIT is selected, the government will set a minimum price, t, for renewable energy electricity to achieve the renewable quota,

$\overline{q}$. The minimum price to be paid for renewable energy under FIT is guaranteed by the government for a certain period of time, for example, up to 20-25 years for solar electricity (PV). The Korean government set a minimum price for solar electricity (PV) for 20 years before adopting RPS. Japan, after failing with RPS, again decided to adopt FIT beginning in July 2012 and to hold the price of solar photovoltaics at ￥32/kWh ($416/MWh) for the next 20 years. It is also assumed that the minimum price, t , is set for a given domestic technology level, that it is irreversible and that it is maintained through the second and third stages. The government thus takes into account the marginal cost of the domestic provider when setting the price or quota for renewable energy electricity. Consideration of marginal cost is justified because the objective of renewable energy policy is to accelerate the deployment of domestic renewable energy technology.

The timing of the game is as follows. First, the government decides to implement either FIT or RPS, a decision that is assumed to be irreversible. In the first stage, after the government announces its choice of renewable energy policy, D decides whether to enter the market by investing sunk cost K_1. If D enters the market, the second stage, characterized by Bertrand competition between D and F, begins.[3] Before the third stage starts, D decides whether to make an R&D investment. Note that at this point, even if D successfully enters the market in the second stage, D could choose to make no R&D investment and therefore fail to narrow the technological gap. In the third stage, D and F engage in Bertrand competition.

One important assumption is that D will become competitive with F in the third stage through reduction of its marginal cost to $c_d^2 < c_d^1$. F, as a multinational enterprise, also improves its technology regardless of whether it participates in any given market, thus reducing its marginal cost to $c_f^2 < c_f^1$. It is assumed that because F's technology is mature, the rate of its technological development is slower than that of D. Thus, if D enters the domestic market, thereby gaining sales experience, the technological gap in the third stage can be reduced through an R&D investment of K_2, equalizing the marginal costs of D and F in the third stage, i.e., $c_d^2 = c_f^2$. The total fixed cost for D to enter the market in the

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[3] D and F are heterogeneous in that they have different marginal costs.

second stage and to minimize the technological gap with F in the third stage is $K = K_1 + K_2$.

If D enters the market in the third stage rather than the second stage, it must spend $K_1 + K_2'$, a cost greater than $K_1 + K_2$, to become fully competitive with F. To simplify the discussion, we additionally assume that D would not enter the market only in the third stage due to substantial R&D costs $K_1 + K_2' = \infty$. These assumptions can be justified as follows. Generally, the development of a given technology follows an S-curve. In particular, F's technology, which has already undergone substantial development, may develop concavely, whereas D's technology may follow a convex path. Under this theory, the above assumptions are not unrealistic. Formation of a policy by which D may achieve the same level of technology as F is also an important issue but is more closely related to technology policy, which is beyond the scope of this study. Therefore, this issue is not addressed in this paper. Track records and experience in demonstration are very important factors in the renewable energy technology industry. If D chooses not to enter the market in the second stage, then the technological gap widens considerably, and catching up in the third stage becomes more difficult. In such a situation, D's R&D expenditures could rise sharply, as D is a latecomer that lacks experience in demonstration and faces a widened technological gap.

Consumer demand for electricity is price inelastic.4) It is also assumed, under either RPS or FIT, that renewable energy sources are first used to meet electricity demand and that the remaining demand is met by fossil fuels. Under RPS, the government sets the minimum amount of renewable energy electricity as a quota, which will be the total amount of electricity obtained from renewable sources, due to the relatively high marginal costs of renewable energy. Under FIT, the price of renewable energy electricity is fixed at t to achieve at least the quota. The renewable energy power generator (P) would then supply as much energy as it can until it earns negative profits. The supply of renewable electricity, at a price of t, will equal or exceed the quota, leading to the same or a higher total average price for electricity and the same or a lower consumer surplus under FIT than under RPS.5)

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4) It is widely recognized that the demand for electricity is inelastic. See Jensen and Skytte (2003).

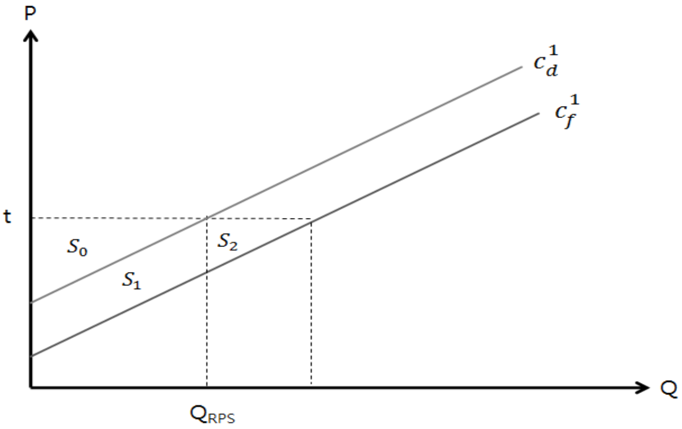
5) In a competitive market, the retail price of electricity is affected by the elasticity of electricity. If the renewable energy supply is inelastic, the price of electricity increases. See Jensen and Skytte (2003), Fischer (2006), and EC Directorate-General Environment (2005).

Ⅲ. Outcomes

When FIT is implemented in the second stage, the producer surplus from purchasing equipment from the foreign producer (F) will be $S_0 + S_1 + S_2$(see Figure 1). Therefore, P's net profit will be $\Pi_{FIT}^{p} = S_0 + S_1 + S_2 - \delta - p_f$, where p_f denotes the price of foreign equipment. Similarly, under RPS, the producer surplus from purchasing equipment from F will be $S_0 + S_1$, and net profit will be $\Pi_{RPS}^{p} = S_0 + S_1 - \delta - p_f$.[6] However, if P decides to purchase equipment from the domestic producer (D), then the producer surplus and net profit of P will be the same under FIT and RPS: the producer surplus will be S_0, and P's net profit will be $S_0 - p_d$.

Using a similar approach, in the third stage, the producer surplus from purchasing equipment from F will be $S_0 + \widetilde{S_1} + \widetilde{S_2}$, where $\widetilde{S_1} > S_1$, and $\widetilde{S_2} > S_2$(see Figure 2). Thus, the net profit that P gains in the third stage will be $\Pi_{FIT}^{p} = S_0 + \widetilde{S_1} + \widetilde{S_2} - \delta - p_f$, where p_f denotes the price of foreign equipment. In the same scenario but under RPS, the domestic producer's (P's) surplus will be $S_0 + \widetilde{S_1}$, and P's net profit will be $\Pi_{RPS}^{p} = S_0 + \widetilde{S_1} - \delta - p_f$. However, if P decides to purchase equipment from D, then the producer surplus and P's net profit will be the same under FIT and RPS: the producer surplus will be $S_0 + \widetilde{S_1}$, and the net profit will be $S_0 + \widetilde{S_1} - p_d$.

Figure 2. Surplus of the renewable energy power generator in the second stage



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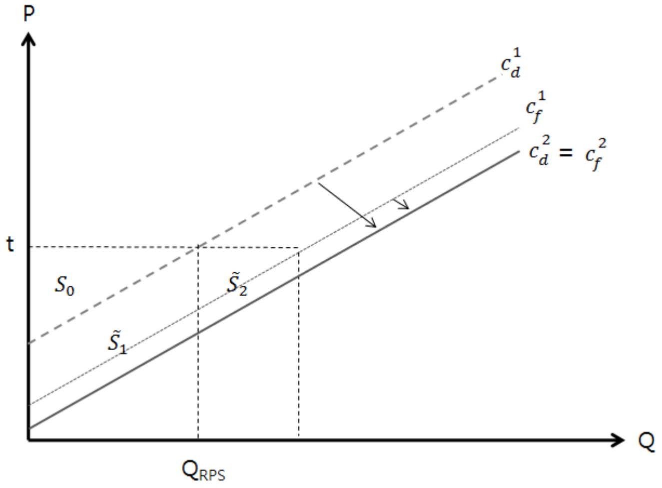
6) Menanteau et al. (2003) compared FIT and RPS in the context of dynamic efficiency, concluding that the difference in producer surplus between FIT and RPS would affect the level of R&D investment.

Figure 3. Surplus for the renewable energy power generator in the third stage



If D enters the market without incurring a sunk cost, then F becomes a monopoly due to D's lack of competitiveness in the upstream market. However, F cannot extract the producer surplus from P due to the monopsony power of P. Let us assume that P and F, which are vertically related, split the net profit earned in the domestic market. P and F take as much as μ and $1-\mu$, respectively, of total profit, where μ takes a value between 0 and 1.

The value of the parameter μ depends on the bargaining power between the two parties. To analyze foreign price bargaining power, we do not consider the case where one party has sufficient bargaining power to make a 'take-it or leave-it' offer. Thus, we assume that both parties have bargaining power and that the surplus is divided into μ and $1-\mu$. If P and F are conducting a transaction, and F is the only supplier in the market, the profit of F under FIT is $\Pi_f = (1-\mu)(S_0 + S_1 + S_2 - \delta)$, while that of F under RPS is $\Pi_f = (1-\mu)(S_0 + S_1 - \delta)$. Correspondingly, the profit of P under FIT is $\Pi_{FIT}^p = \mu(S_0 + S_1 + S_2 - \delta)$, while that obtained under RPS is $\Pi_{RPS}^p = \mu(S_0 + S_1 - \delta)$.

Additionally, we assume that the relationships between the components of the surplus can be described as $S_2 < S_0$, $\widetilde{S}_1 < \widetilde{S}_2$ and $\widetilde{S}_1 < S_1 + S_2$. These relationships are technical assumptions adopted to simplify calculations and reduce the number of possible cases. If they are not satisfied, the results of this paper do not change.[7] Among these conditions,

$\widetilde{S}_1 < S_1 + S_2$ is important, as it internalizes efforts made by the domestic provider (D) to develop technology, given a particular range of transaction costs; this condition will be explained in the following subsection in more detail.[8)]

We consider three cases where the transaction cost δ affects renewable energy generator P's decision to purchase equipment from either D or F. If δ is significant ($S_1 + S_2 < \delta$), P will purchase equipment from D; if it is negligible ($\delta < S_1$), P will purchase it from F. However, if δ falls within a range in which the bargaining power of P affects its decision about whether to purchase from D or F, the optimal choice of renewable energy policy is RPS rather than FIT.

3.1. $S_1 < \delta < S_1 + S_2$

First, let us consider a scenario in which the government implements FIT. When D spends a sunk cost of K_1 to enter the market in the second stage, D and F can compete on price in the market. Because F has a comparative advantage over D, F dominates the domestic market by setting the price at $S_1 + S_2 - \delta (> 0)$(to be precise, the price is less than $S_1 + S_2 - \delta$ by $\epsilon > 0$). D therefore has no incentive to enter the market because it will only lose its initial investment of K_1. However, if D decides not to enter the market, F will wield its monopoly power and set the price at $p_f = (1 - \mu)(S_0 + S_1 + S_2 - \delta)$. In this scenario, P's profit is $\Pi^{p}_{FIT} = \mu(S_0 + S_1 + S_2 - \delta)$ in the second stage.

Now consider D's decision to invest K_2 in the third stage. If D decides not to invest K_2 after investing the sunk cost of K_1, D will only be able to supply the technology at a marginal cost of c_d^1, which will widen the gap in cost competitiveness between D and F. If D decides to invest $K_2{}'$ after not investing the sunk cost of K_1, it will not be

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7) The condition $S_2 < S_0$ ensures that P earns a profit greater than zero and hence participates in the market for all $\delta \in (S_1, S_1 + S_2)$under RPS. $\widetilde{S}_1 < \widetilde{S}_2$ is assumed in order to simplify the model.

8) If the condition $\widetilde{S}_1 < S_1 + S_2$ does not hold, RPS results in greater social welfare for all δ , where $S_1 < \delta < S_1 + S_2$ even though D does not invest in R&D for renewable energy technology. This case is not of interest in the present paper, as we wish to compare RPS and FIT in the context of R&D investment and transaction costs for imported goods.

profitable for D to invest $K_1 + K_2^{'}$, which is assumed to be infinite, in seeking to become fully competitive with F. D therefore does not enter the market in the third stage either. In the third stage, P obtains a pay-off of $\Pi_{FIT}^{p} = \mu(S_0 + \widetilde{S_1} + \widetilde{S_2} - \delta)$, similarly to the second stage.

In sum, the domestic renewable energy market in the second and third stages will be dominated by F, and the total domestic producer surplus gained by P and D will be $\mu(2S_0 + S_1 + \widetilde{S_1} + S_2 + \widetilde{S_2} - 2\delta)$.9)

Now, let us consider a scenario in which the government implements RPS. In this case, the total surplus gained by P in the second stage is $S_0 + S_1$ if it purchases from F and S_0 if it purchases from D. Suppose that D enters the market in the second stage and competes with F. For P, purchasing from D saves a transaction cost of δ. D then has a competitive advantage over F of $\delta - S_1$. Note that this scenario assumes that $\delta > S_1$. Thus, through Bertrand competition, D sets the price of its equipment at $p_d = \delta - S_1$ and captures all sales in the domestic market in the second stage. However, it is important to note that D cannot monopolize the market, unlike in the case of FIT, because F exists as a potential competitor under Bertrand competition. As a result, the profit gained by P in the second stage under RPS is $\Pi_{RPS}^{p} = S_0 - p_d = S_0 + S_1 - \delta (> 0)$. Furthermore, the profit gained by D is $\delta - S_1$. If the sunk cost K_1 is considered, then the net profit of D in the second stage is $\delta - S_1 - K_1$.

Assuming that D entered the market in the second stage, gaining sales and operational experience, D can make an R&D investment of K_2 in the third stage, narrowing the technological gap with F. In this case, the marginal cost of producing renewable energy power generators in the third stage is equal for D and F. Thus, D gains a comparative advantage over F as a result of the transaction cost, δ. Therefore, when D makes an R&D investment of K_2 in the third stage, the price of D's equipment is $p_d = \delta$, and D dominates the domestic market. P's profit in the third stage is then $\Pi_{RPS}^{p} = S_0 + \widetilde{S_1} - p_d = S_0 + \widetilde{S_1} - \delta$, and D obtains a profit of δ.

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9) It is assumed that payoffs are not discounted over time.

The total domestic producer surplus under RPS, which is the sum of all profits gained by P and D in the second and third stages, is $2S_0 + \widetilde{S_1} - K$, where $K = K_1 + K_2$; the net profit of D is $2\delta - S_1 - K$.

It is important to note that, given the parameter δ, a particular value of K may cause D to decide not to invest in R&D in the third stage. For example, if D earns a positive profit by entering the market in the second stage and finds that profit earned in the second stage exceeds profit that could be earned in the second and third stages by making the R&D investment, then it would have no incentive to enter the third stage by spending K_2 on R&D. For example, in the case of $\widetilde{S_1} < \delta < S_1 + S_2$ under RPS, D can earn a positive profit in the third stage even if it does not catch up with F: under price competition, D sets the price at $p_d = \delta - \widetilde{S_1}$ and captures all sales in the domestic market in the third stage. In view of this scenario, the following lemma is derived. Subsequent analysis will be limited to the scope of this lemma.

Lemma 1 Under RPS, if $2\delta - S_1 - K_1 - K_2 > 0$ and $K_2 < \bar{K}_2$, where $\bar{K}_2 = \min\{\delta,\ \widetilde{S_1}\}$ then D has an incentive to make an R&D investment of K_2 for all values of δ, where $S_1 < \delta < S_1 + S_2$.

Proof: First, let us consider the condition $S_1 < \delta < \widetilde{S_1}$. If D does not make an R&D investment after entering the second stage, the domestic market in the third stage will be dominated by F, which initially has a comparative advantage in technology. Because the given condition is $S_1 < \delta < \widetilde{S_1}$, F gains a comparative advantage over D of $\widetilde{S_1} - \delta$ under RPS; thus, D's profit is zero. Therefore, D's total profit in the second and third stages is $\delta - S_1 - K_1$. However, if D decides to make an R&D investment in the third stage, D will dominate the market and, as noted above, D's total profit in both stages becomes $2\delta - S_1 - K_1 - K_2$. In sum, D will make an R&D investment if the following two conditions are met:

(Participation constraint) $2\delta - S_1 - K_1 - K_2 > 0$ (1)

(Incentive constraint) $2\delta - S_1 - K_1 - K_2 > \delta - S_1 - K_1$ (2)

From equations (1) and (2), before D enters the market in the third stage, D will make an R&D investment if $2\delta - S_1 - K_1 - K_2 > 0$ and $K_2 < \delta$.

Next, let us consider the case where $\widetilde{S}_1 \leq \delta < S_1 + S_2$. In this case, even if D does not make an R&D investment after it enters the market in the second stage, it will have a comparative advantage over F of $\delta - \widetilde{S}_1$ in the third stage due to significantly high transaction costs. In this case, the total profit of D over all stages is $2\delta - S_1 - \widetilde{S}_1 - K_1$. However, if D makes an R&D investment in the third stage, its profit is $2\delta - S_1 - K_1 - K_2$. In sum, the participation constraint and the incentive constraint for D to make an R&D investment are as follows:

(Participation constraint) $2\delta - S_1 - K_1 - K_2 > 0$ (3)

(Incentive constraint) $2\delta - S_1 - K_1 - K_2 > 2\delta - S_1 - \widetilde{S}_1 - K_1$ (4)

From equations (3) and (4), we know that D will make an R&D investment if $2\delta - S_1 - K_1 - K_2 > 0$ and $K_2 < \widetilde{S}_1$.

If $\delta < \widetilde{S}_1$, then the condition $K_2 < \delta$ should hold, while the condition $K_2 < \widetilde{S}_1$ should hold for $\delta > \widetilde{S}_1$. Equations (3) and (4) are satisfied under the condition that $K_2 < \bar{K}_2$, where $\bar{K}_2 = \min\{\delta,\ \widetilde{S}_1\}$. (End of proof)

Table 1. Pay-off matrix of the participants ($S_1 < \delta < S_1 + S_2$)

Classification		Π^P	Π^D	Π^F
FIT	Phase II	$\mu(S_0 + S_1 + S_2 - \delta)$	No Entry	$(1-\mu)(S_0 + S_1 + S_2 - \delta)$
	Phase III	$\mu(S_0 + \widetilde{S}_1 + \widetilde{S}_2 - \delta)$	No Entry	$(1-\mu)(S_0 + \widetilde{S}_1 + \widetilde{S}_2 - \delta)$
	Total	$\mu(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta)$	0	$(1-\mu)(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta)$

Classification		Π^P	Π^D	Π^F
RPS	Phase II	$S_0 + S_1 - \delta$	$\delta - S_1 - K_1$	0
	Phase III	$S_0 + \widetilde{S}_1 - \delta$	$\delta - K_2$	0
	Total	$2S_0 + S_1 + \widetilde{S}_1 - 2\delta$	$2\delta - S_1 - K$	0

The analysis will be conducted by introducing a situation in which Lemma 1 is always valid. When D enters the market in the second stage, it becomes fully competitive with F through an R&D investment in the third stage. Under this premise, the pay-off matrix of the participants is summarized as in Table 1.

According to Table 1, the producer surplus, i.e., the sum of P's and D's profits $(\Pi^{P+}\Pi^{D})$ over the second and third stages, is higher under RPS than under FIT, given that $2S_0 - \widetilde{S}_1 - K > \mu(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta)$. Note that the condition $2S_0 + \widetilde{S}_1 - K > 0$ holds when Lemma 1 is valid.10) Therefore, the following propositions can be derived:

Proposition 1 If $S_1 < \delta < S_1 + S_2$, and $\mu < \dfrac{(2S_0 + \widetilde{S}_1 - K)}{(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta)}$, then RPS yields a higher producer surplus than FIT.

Proposition 1 can be explained as follows. In the absence of a transaction cost for imported goods, if P purchases foreign equipment, which has a relatively low marginal cost, producer surplus in the second stage is higher under FIT than under RPS. However, if a transaction cost exists and is sufficiently high, D has a comparative advantage over F. Hence, D is willing to enter the market under RPS, while it cannot find an opportunity to enter the market under FIT. Once D enters the market in the second stage, it can gain a comparative advantage in the market by moving up its learning curve through sales experience and investing in R&D, thus catching up with F in the third stage. In the FIT scenario, however, D cannot enter the market in the second stage, and it incurs a higher

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10) From $K < 2\delta - S_1$ and $\delta < S_1 + S_2$, we have $K < 2S_2 + S_1$. Because $S_2 < S_0$ and $S_1 < \widetilde{S}_1$, we derive the condition that $K < 2S_2 + S_1 < 2S_0 + \widetilde{S}_1$.

R&D investment expenditure to catch up with F in the third stage; hence, D eventually falls behind in the market. In other words, RPS can be utilized as a strategic tool that allows D to enter the market and develop technology. Furthermore, through the result of proposition 1, a second proposition is obtained:

Proposition 2 For all K that satisfy Lemma 1, if $\mu < \hat{\mu}$, where $\hat{\mu} < \frac{2S_0 + \widetilde{S}_1 - K}{(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta} < 1$, and $S_1 < \delta < \widetilde{S}_2$, RPS is a favorable policy for a renewable energy power generator and a domestic renewable technology provider. However, if $\hat{\mu} < \mu < 1$, FIT becomes more favorable.[11]

Proof: As the above proposition can easily be proven with simple algebra, an explanation of the proof is omitted.

Proposition 2 indicates that the less price bargaining power (μ) P has, the higher the producer surplus is under RPS compared with FIT;[12] this relationship can be intuitively understood. In the FIT scenario, producer surplus is only generated by P, not by D. If P has bargaining power over F and can take most of the surplus yielded in the vertically related market, then there is no incentive for the government to choose RPS to strategically induce D to enter the market.

3.2. $\delta < S_1$

Given the scenario in which the transaction cost is less than S_1, F, with its comparative advantage, dominates the market. As assumed earlier, given that the R&D cost needed for

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[11] If $\widetilde{S}_1 < \delta < S_1 + S_2$, for some K, RPS results in higher social welfare for all μ, a case that can be ignored because it is of little economic interest.

[12] μ under FIT could be larger than under RPS, given that the renewable energy power generator (P) may have more bargaining power over F under FIT than under RPS. Under RPS, the designated utilities are required to provide at least the amount $\alpha\overline{Q}$ of renewable electricity, placing P in a weak position relative to F. This weak position does not change the result of proposition 2, provided that $\mu < \hat{\mu}$.

D to catch up with F increases sharply, D will not enter the market, and F will take the entire market share.

The full renewable energy electricity supply is equal to the quota set by the government under RPS, while it is equal to or greater than the quota under FIT, as in the latter scenario, P gains greater profit by providing more renewable energy electricity at a price of t. Hence, more renewable energy power is supplied at a price of t under FIT than under RPS, leading to higher consumer price of electricity under FIT than under RPS.

3.3. $S_1 + S_2 < \delta$

Due to high transaction costs, F is always at a comparative disadvantage with respect to price competition with D. First, consider the case where $S_1 + S_2 < \delta < \widetilde{S}_1 + \widetilde{S}_2$. Regardless of the government's choice of policy, the market in the second and third stages is dominated by D, which supplies the quota of renewable energy electricity set by the government under both regimes. F, by contrast, makes no sales in the second stage because high transaction costs act as an entry barrier. D will make an R&D investment of K_2 in the third stage, leading to equality between its marginal cost and that of the foreign producer. Otherwise, F, as a multinational enterprise, will enter the market with a competitive price. Hence, the profits of P and D are equal under both RPS and FIT.

Now, consider the case where $\widetilde{S}_1 + \widetilde{S}_2 < \delta$. Due to significant transaction costs, D dominates the market in both periods, while F makes no sales in both periods. As in the previous case, where $S_1 + S_2 < \delta < \widetilde{S}_1 + \widetilde{S}_2$, P supplies only the minimum amount of renewable energy electricity, where the surplus of P and D under RPS is the same as under FIT. Because D has a comparative advantage in the market, D may be uninterested in making an R&D investment in the third stage after participating in the second stage. Even if D does not invest in the third stage, P and D earn the same profits under both RPS and FIT.

3.4. Social Welfare Comparison

Social welfare is the sum of consumer surplus and producer surplus. Both surpluses depend on the government's choice of renewable energy policy between RPS and FIT. It is generally accepted that the retail price of electricity increases as the government introduces either RPS or FIT, which reduces consumer surplus.[13)]

The quota of renewable energy electricity should be supplied under RPS, while the minimum price t is set under FIT to achieve the quota at the domestic renewable energy technology level; this price will be paid for renewable energy in both the second and third stages. Consequently, more renewable energy electricity is produced at a lower marginal cost of foreign goods under FIT than under RPS when the foreign producer F participates in the upstream market. Thus, the consumer price of electricity is higher under FIT than under RPS.

When transaction costs are not sufficiently high for the domestic renewable technology provider to catch up with F, D does not enter the market, and F, with its lower marginal cost, captures the entire market. Thus, more renewable energy power is supplied at the price of t under FIT than under RPS, leading to an increase in the wholesale electricity price under FIT and thus an increase in producer surplus but a decrease in consumer surplus. In this case of negligible transaction costs, the overall social welfare comparison between RPS and FIT is ambiguous. However, when transaction costs are sufficiently high for the domestic renewable technology provider to enter the market, but the foreign producer is unable to obtain any market share, producer surplus and consumer surplus are equal under RPS and FIT, leading to equivalent levels of social welfare under the two regimes. The surpluses are equal because, given significant transaction costs, even under FIT, only the required minimum amount of renewable energy is supplied due to high transaction costs. In this case, transaction costs act as an entry barrier for the foreign producer.

Given conditions where P and D earn greater profits under RPS than under FIT, as in propositions 1 and 2, social welfare under RPS is higher than under FIT. Recall that the

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13) However, the retail price of electricity may decrease when fossil fuel-based electricity is less sensitive to supply price and renewable energy supply is sensitive to price.

quantity of renewable energy electricity supplied under FIT is equal to or greater than that supplied under RPS, leading to the same or a higher electricity consumer price. Hence, if P and D together earn higher profits under RPS than under FIT, social welfare is higher under RPS than under FIT. When transaction costs and the bargaining power of P satisfy $S_1 < \delta < S_1 + S_2$ and $\mu < \frac{2S_0 + \widetilde{S}_1 - K}{(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta)}$, respectively, RPS yields a higher surplus for P and D. Therefore, for all K that satisfy Lemma 1, if $\mu < \hat{\mu}$, where $\hat{\mu} < \frac{2S_0 + \widetilde{S}_1 - K}{(2S_0 + S_1 + \widetilde{S}_1 + S_2 + \widetilde{S}_2 - 2\delta)} < 1$ and $S_1 < \delta < \widetilde{S}_2$, RPS results in greater social welfare than FIT. However, if the bargaining power of P is subject to the condition $\hat{\mu} < \mu < 1$, FIT yields greater profits for P and D but does not necessarily yield greater social welfare than RPS.

Ⅳ. Policy Implications and Conclusions

This paper has presented a comparative analysis of how the choice of policy between RPS and FIT affects a firm's choice of intermediate goods between a domestic and a foreign supplier, given the presence of transaction costs. Transaction costs refer to costs incurred when renewable energy equipment is imported from a foreign provider rather than purchased domestically. Korea is a late mover in the renewable energy industry; Korea adopted FIT in 2002 and transitioned to RPS in 2012 as its dominant strategy for promoting the development of renewable energy. To examine Korea's situation, we adopted a competitive model in which a domestic provider had a cost disadvantage over a foreign provider that had developed renewable energy technology long before the domestic provider started its business.

It appears that many observers have favored FIT as a means of accelerating the deployment of renewable energy in the early stages of renewable energy development. RPS may ameliorate a hostile environment for domestic providers, one in which such providers initially face a comparative disadvantage. The intuition is that under RPS, but not under

FIT, the domestic provider may be able to compete against a foreign provider when there are transaction costs. When transaction costs are at a moderate level, RPS is found to create a favorable environment for the domestic producer to enter the market, one that supports the domestic producer as it catches up with the foreign producer. This finding suggests that the Korean government's decision to implement RPS was optimal, given Korea's comparative disadvantage in green energy relative to major developed countries.

However, one criticism of RPS is that, if R&D investment is projected to be high, the domestic producer may not make an effort to develop its technology. Moreover, in this paper, we have assumed that R&D investment has a 100% success rate, but in reality, R&D failure is always possible. Thus, if the possibility of R&D failure is considered, then the domestic producer may be uninterested in making an R&D investment. Therefore, it is important that the government provide support so that domestic producers can successfully gain a competitive edge in the long term.

This paper can be extended in two ways in future research. First, transaction costs are considered an external factor in this analysis. However, one important factor that affects transaction costs is tariffs. Hence, government decisions could become an additional independent variable, and the model could be extended to include endogenous transaction costs and two countries. This possibility implies that the model could be elaborated through a link to strategic trade theory. Second, this paper has shown theoretically that RPS is a favorable policy when transaction costs exist but has presented no empirical support for this result. Therefore, this theory could be verified and supplemented through future empirical research.

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