Science and Public Policy, 46(5), 2019, 648–660
doi: 10.1093/scipol/scz017
Advance Access Publication Date: 5 May 2019
Article

OXFORD

Incumbents' response to demand-side policies: The case of solar and wind power sectors

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Abstract

This work examines incumbents' responses to two demand-side policies by focusing on their investment in new sustainable technologies. It focuses on how economic incentive and regulatory policies shape the market environment and this affects incumbents' investment in new technologies. By using mediation and difference-in-difference regression models, it examines incumbent utilities' investment in solar and wind power plants. It reveals that incumbent utilities under the economic incentive policy more invest in the solar and wind power than those under the regulatory policy, as it places stronger competitive pressure on incumbent utilities to adapt to the new technology. Further, incumbents prefer alternative technologies complementary to their existing competences and expand their investment in a global market under policy-induced competitive pressures.

Key words: demand-side policies; economic incentive policy; regulatory policy; incumbent; competitive pressure; sustainable technologies

1. Introduction

Many countries have introduced demand-side policies to facilitate the diffusion of new technologies. Demand-side policies refer to government policies that stimulate market demand by reducing uncertainty for suppliers and buyers. They are widely adopted to stimulate new technologies for social problems such as climate change that are associated with high uncertainty and risk (Edler and Boon 2018). New technologies related to social problems are generally less competitive than mainstream technologies. In this environment, demand-side policies provide space where actors can experiment new technologies. This space attracts a broad range of stakeholders including established incumbents.

A role of incumbents in diffusion of new technologies is a double-edged sword. Though standard models predict that incumbents are likely to delay the introduction of new technologies (Tushman and Anderson 1986; Utterback 1994), recent studies emphasized that incumbents' response can be diverse because some can benefit from the emergence of new technologies under the specific conditions (Hill and Rothaermel 2003; Jiang *et al.* 2011; Kishna *et al.* 2017). The large incumbents have strong capabilities and experience and it can contribute to the expansion of new technologies by adding new ideas and gaining legitimacy from stakeholders (Choi *et al.* 2011; King and Tucci 2002; Kishna *et al.* 2017). The level of incumbents' investment in new technologies could depend on the market environment, which is largely influenced by governments' demand-side policies and its impact is particularly significant for the case of sustainable technologies heavily supported by governments aiming at public wellbeing.

However, few prior works have investigated how demand-side policies have shaped the market environment and how these changes affect the behavior of incumbents in the rise of new technologies (Carroll and Khessina 2005; Weigelt and Shittu 2016). This study offers new insights to research on demand-side policy and industry life cycle literature. Sustainable technology emergence brings about heterogeneous industry structures consisting of diverse technological designs and market segments that allow incumbents to opt for diverse options including not only ignorance, but also adaptation and reposition (Uzunca 2018; Wang and Shaver 2014). This study examines how demand-side policies shape a market environment, leading to distinctive incumbents' investment for long-term sustainability (Weigelt and Shittu 2016).

An electric power generation sector was chosen to examine the incumbents' response to demand-side policies. Conventional incumbents in the electric power generation are vertically integrated electric utilities that own both the electric power generation and distribution facilities. There are two main approaches in demand-side policies in an energy sector: economic incentive and regulatory (or command-and-control) policies (Stavins 1998; Tietenberg 1990). Feed-in tariffs (FiTs) correspond to an economic incentive policy because they drive market growth by providing electric utilities and independent power producers with long-term purchase contracts and guaranteed prices for electricity generated from renewable energy sources. Renewable portfolio standards (RPSs), on the contrary, correspond to a regulatory policy that mandates a renewable power generation target for electric utilities; if such companies fail to achieve the target, a penalty is imposed.

This study examines the relationship between economic incentive and regulatory policies and the investment of incumbent utilities in the solar and wind power. I hypothesize that incumbents under economic incentive policies (e.g., FiTs) are more likely to invest in renewable energy technologies than those under regulatory policies (e.g., RPSs) with direct and indirect causal links. First, incumbents have direct financial and economic benefits from the economic incentive policies like other market players. This is a direct effect. Second, economic incentive policies are more likely to generate competitive pressure (Anderson and Tushman 2001) from the renewable energy technology than regulatory policies in the market. This is an indirect effect and has been inadequately explored to date. In contrast, regulatory policies do not threaten incumbents' dominant positions in the market either because their goal is to achieve a specific environmental target rather than inducing market competition. Further, I examine how incumbents respond to such competitive pressure. I test which technology and market strategies they choose in response to competitive pressure induced by government policies and show that incumbent prefer a technology and market that demand their existing competences and complementary assets.

This study contributes to the demand-side policy and industry life cycle literature. First, it shows an indirect link via competitive pressure between demand-side policies and incumbents' investment in new technologies. Prior studies focused on a direct effect of demand-side policies on firms' investment in new technologies, but they have paid little attention to how demand-side policies differently shape the market environment and how these changes influence the incumbents' investment activities in new technologies (Carroll and Khessina 2005; Weigelt and Shittu 2016).

Second, it elaborates the discussion on demand-side policies by analyzing the effects of two types of demand-side policies on incumbents' investment in new technologies. Prior studies mostly focused on how overall and one type of demand-side policies influence firms' willingness to invest (Hoppmann *et al.* 2013; Peters *et al.* 2012; Weigelt and Shittu 2016; Wesseling and Edquist 2018). However, I distinguish economic incentive and regulatory policies and show that the economic incentive policy shapes a competitive market environment in contrast to the regulatory policy (Weigelt and Shittu 2016) and this induces incumbents to choose adaptive strategies (Doh and Pearce 2004).

Third, I examine how incumbents respond to policy-induced competitive pressure with a focus on technology and market strategies. Incumbents are generally reluctant to adopt new technologies. Thus, when policy-induced competitive pressure enforces them to adopt new technologies, they are likely to benefit from their existing competences and resources by choosing a specific strategy. It provides theoretical explanations of incumbents' investment behaviors for managing risks and capturing new opportunities associated with policy-induced competitive pressure. It contributes to incumbents' behavior literature (Uzunca 2018; Wang and Shaver 2014).

2. Theoretical background

Most of the prior works on incumbents' responses to new technology emergence have focused on organizational conditions (Cozzolino *et al.* 2018; Jiang *et al.* 2011). However, various market environments can induce heterogeneous reactions of incumbents to new technologies. Indeed, a government is one of the key players in shaping the market environment for sustainable technologies due to high uncertainties and risk in sustainable technologies (Edler and Boon 2018) and scholars have paid attention to firms' response to government actions (Doh and Pearce 2004; Peters *et al.* 2012).

The previous literature underscores the importance of two dimensions in the discussion of firms' responses to government policies. The first dimension is the type of government policy. Scholars have categorized supply and demand-side policies designed for new technologies extensively (Choi 2018; Hoppmann *et al.* 2013; Peters *et al.* 2012). Supply-side policies refer to R&D policies that encourage innovation activities of private firms, while demand-side policies refer to market stimulation policies that create early market demand. In particular, demand-side policies have attracted a great deal of attention recently because they bring about diverse indirect effects on firms' behavior by shaping the market environment for sustainable technologies (Edler and Boon 2018; Hoppmann *et al.* 2013).

The second dimension is the effect of the policies on the upstream and downstream of emerging industries (Choi and Anadón 2014). In the upstream industry, both supply and demand-side policies help firms increase innovation outcomes (Peters *et al.* 2012) and this technology stock drives the manufacturing cost of new tech products down (Taghizadeh-Hesary *et al.* 2018). In the downstream industry, government policies enable firms to invest in the deployment of new technologies (Weigelt and Shittu 2016) by creating new market demand.

Recent studies have focused on the effects of demand-side policies on innovation and manufacturing outcomes in the upstream industry. For example, they explored the spillover effects associated with innovation and manufacturing outcomes across borders as new market demand is created by demand-side policies (Choi and Anadón 2014; Peters *et al.* 2012; Schaeffer *et al.* 2004). It attracts diverse and international market players and generates competitive pressure for both existing and new market players in the domestic upstream industry. In this market environment, firms generate positive outcomes. For example, Pillai (2015) explained that the entry of Chinese manufacturing firms into the solar PV manufacturing sector lowered the global solar PV panel price.

However, little is known about how demand-side policies shape the downstream market environments and particularly how these changes affect the incumbents' deployment activities in the downstream industry (Weigelt and Shittu 2016). This poses an interesting research question because it may offer the possibility that incumbents who possess complementary downstream assets such as electric power generation and transmission facilities of electric utilities can compete with newcomers and jump into the new industry (Hill and Rothaermel 2003). Thus, this study bridges the literature on demand-side policy and the industry life cycle literature (Carroll and Khessina 2005; Weigelt and Shittu 2016) by observing incumbents' responses to demand-side policies for new technologies in the downstream industry.

3. Hypotheses development

In general, prior studies have investigated the impact of overall and one type of demand-side policies on firms' activities (Hoppmann *et al.* 2013; Peters *et al.* 2012; Weigelt and Shittu 2016; Wesseling and Edquist 2018). However, types of demand-side policies are heterogeneous across countries and their effects may differ. In this article, I introduce economic incentive and regulatory policies among demand-side policy measures. These two policies have been widely used to achieve policy goals by stimulating sustainable energy market demand. Up to date, researchers have paid attention to economic incentive policies allowing more flexibility in achieving policy goals by generating various pathways. For example, in the electricity market, most research has concluded that economic incentive policies (i.e., FiTs) are superior to regulatory policies (i.e., RPSs) for promoting the deployment of renewable energy technologies as the guaranteed price directly reduces the investment risk and provides stability to adopters (European Commission 2008; Rodríguez *et al.* 2015).

In this study, I argue that incumbents set more investments in new technologies under an economic incentive policy than under a regulatory policy, applying not only the direct policy effect examined by prior policy studies, but also the indirect policy effect drawn from industry life cycle theory. On the one hand, the presence of new technologies threats incumbents' dominant position in the market (Kim 2013; Weigelt and Shittu 2016), putting their financial performance at risk (Di Cosmo and Valeri 2014; Frondel *et al.* 2010). This may create greater competitive pressure for incumbents, increasing market uncertainty. It makes them to adapt to new technologies using their complementary assets (Aghion *et al.* 2009; Wang and Shaver 2014). On the other hand, greater competitive pressure induced by government policies in new market also can give an opportunity to incumbents because incumbents have existing resources and customers while entrants have a difficulty in securing resources and customers in competitive market.

In contrast, regulatory policies impose sanctions on established firms to achieve specific environmental targets. When complying with government regulations, incumbents can choose their strategic options, and these influence the overall market. For example, in the electric power generation sector, RPSs force incumbent electric utilities to produce a specific percentage of electricity from renewable energy sources. Regulatory policies guide new investment and incumbents do not invest in new technologies beyond the regulation level in uncertain environments (Weigelt and Shittu 2016). Furthermore, incumbents can choose how to comply with regulations. For example, in the electric power generation sector, they can establish own power plants and also purchase renewable energy credits from independent power producers. These give market power to incumbents rather than entrants. Low competitive pressure reduces the incentive of incumbents to adopt new technologies aggressively (Holmes *et al.* 2012).

H1a. Economic incentive policies directly encourage incumbents to invest more in new technologies as compared to regulatory policies

H1b. Economic incentive policies indirectly encourage incumbents to invest more in new technologies by increasing competitive pressure on incumbents as compared to regulatory policies

Then, how do incumbents respond to policy-induced competitive pressure? Incumbents prefer a specific strategy among diverse alternatives depending on market environment and government policies (Doh and Pearce 2004; Jiang *et al.* 2011; Pettus *et al.* 2017; Weigelt and Shittu 2016). In this article, I focus on technology and market strategies. Scholars paid attention to types of incumbents' resources and competences when incumbents choose their strategy. From an incumbent perspective, investment in new technologies requires different resources and competences from existing ones. If they participate in new sectors due to policy-induced competitive pressure, they are likely to choose a technology and market that best uses their existing competences and complementary assets.

As a result, on the one hand, choosing a technology close to their existing competences is one strategy to increase the use of complementary assets (Kim, 2013). In the case of the electric power generation sector, incumbent utilities have operated large fossil-fuel power plants efficiently. It makes them to prefer wind power over solar power because the former has some similar features with their existing power plants. In detail, wind power has market competitiveness in large-scale plants (DeCarolis and Keith, 2006). Thus, electric utilities as well as other market players establish large-scale wind power plants to enjoy the capital cost advantage of the wind power, but it requires firms to have competences in operating large-scale wind power plants efficiently. At this moment, incumbents' experience in existing power plants is helpful. In addition, wind power plants' output power variability is more stable than the solar power case (Budischak *et al.* 2013). These features are more compatible with incumbent utilities' large fossil-fuel power plants, enabling them to consider the wind power more seriously than the solar power in response to competitive pressure induced by economic incentive policies.

On the other hand, incumbents can also choose a specific market strategy in response to policy-induced pressure. First, they adapt to the new sector in the home market. When the emergence of the new technology threats their positions in the home and primary market, they try to adapt to new environment. The earlier discussion in Hypothesis 1 focuses on this option. Second, incumbents can reposition their market strategies and seek new opportunities in other markets (Pettus *et al.* 2017; Uzunca 2018; Wang and Shaver 2014). Reposition refers to incumbents' actions that rearrange their business positions and domains along with the changing business environments.

Prior studies mostly focused on the firms' market repositioning driven by business opportunities. When new market opportunities emerge, firms aggressively reposition their market to extend their business. However, the competition- and policy-driven repositioning discussed in this article has less investigated in comparison to opportunity-driven repositioning (Wang and Shaver 2014). Though incumbents are reluctant to change their domains by nature, threat, and competition can drive them to reposition in the market. Incumbents under policy-induced competitive pressure can reposition their strategy by extending their geographical locations because they have developed resources related to new technologies for the home market. It enables them to leverage these resources again for other countries (Pettus *et al.* 2017). Therefore, we can predict that incumbents diversify the geographical portfolio under significant pressure caused by the economic incentive policy. However, incumbents under the regulatory policy have less domestic competitive pressure, and then it does not induce their market repositioning behavior.

H2a. Incumbents respond more to a new technology complement to their existing competences under policy-induced competitive pressure

H2b. Incumbents diversify their geographical markets in response to policy-induced competitive pressure

4. Methodology and data

4.1 Research setting and data treatment

I tested the hypotheses in the electric power generation sector. Vertically integrated electric utilities are incumbents dominating electricity generation activities based on own distribution systems. However, incumbents have faced a great challenge as renewable energy sources arise as an alternative model to fossil-fuel power plants. In the 1990s, electric utilities were reluctant to adopt renewable energy sources. However, there was a change in their attitudes toward renewable energy caused by governmental actions and structural changes in the industry during the 1990–2000s (Peters *et al.* 2012; York *et al.* 2016).

As introduced earlier, FiTs and RPSs are two of the most common deployment policies implemented as economic incentive and regulatory policies in the electric power generation sector, respectively. I focused on solar and wind power technologies because they are key renewable energy technologies and have distinctive features. I limited the timeframe from 1998 to 2008 because demand-side policies are mostly influential in the emerging phase and the global financial crisis starting at 2008 may have had a systematic impact on deployment activities after 2009; indeed, many countries adopting FiTs amended their contract conditions owing to budget constraints.

The data were restricted to the top 50 vertically integrated electric utility companies globally, as classified by Compustat under Global Industry Classification Standard (GICS) code 551010 (Electric Utilities) and 551030 (Multi-Utilities), based on the revenues of electric power generation and transmission facilities in 2010. GICS defines electric and multi-utilities as firms that produce or distribute electricity. I removed utilities that have only a distribution business from the GICS category. I limited the sample to the top 50 utilities because their investment information is more accurate and available than that of smaller firms (Gulati 1995; Phelps 2010). These top 50 electric utilities globally make up 65% of the two GICS segments. The data cover diverse geographical locations, consisting of 21 companies from North America (20 companies in the USA and one company in Canada), 16 from Europe (five companies in Germany, two companies each in France, the UK, and Spain, and one company each in the Czech Republic, Finland, Italy, Portugal, and Sweden), eight from Asia (six companies in Japan and one company in both Malaysia and South Korea), four from South America (three in Brazil, and one in Chile), and one from Russia. They indicate that the top 50 electric utilities represent the global market quite well.

One concern has been still raised about a profitability difference between sample and non-sample firms. However, the electric utility sector is highly regulated and thus, there may be a marginal difference in profitability across firms. To confirm this, I conducted a t-test to compare EBIT and EBIT per total revenue between sample firms and non-sample firms. For the case of EBIT, the average value of the top 50 sample firms is twice as large as that of the non-sample firms because of their firm size, but a *t*-test shows that they are not statistically different. For the case of EBIT per total revenue, the average values of two groups are similar and a *t*-test indicates that they are not statistically different, either. Thus, I conclude that electric utilities in both the sample and non-sample will respond to demand-side policies consistently regardless of their profitability.

Global top 50 firms also contain cases with various FiT/RPS policy environments. Most countries choose either FiTs or RPSs in the research sample, while few adopt both. In case, I conducted the analyses by dropping all dual policy cases and obtained consistent results, indicating that I have no reason to believe that a complementary effect caused by dual policy cases produces systematic bias in the results.

4.2 Empirical strategy

Each data point was measured at the firm and local location levels. I used a mediation model to break down direct and indirect policy effects. A competitive pressure variable served as a mediator that proxies for the influence of government policies on electric utilities' plant capacity in the renewable energy market. In general, a mediation effect exists when the following three conditions are satisfied: (1) the independent variables significantly affect the dependent variables without the mediators (baseline model), (2) the independent variables significantly affect the mediators (mediator model), and (3) the mediators significantly influence the dependent variables after the independent variables are controlled for (full model) (Baron and Kenny 1986).

This study examined the main hypothesis by using generalized DiD linear regression models. DiD models have been a central empirical strategy over recent years when estimating policy effects (Carley *et al.* 2017; Gruber and Hungerman 2008). A simple DiD regression could not be adopted here because the models include multiple time periods and multiple control groups (a comparison with a different set of countries over time). Generalized DiD regressions (Carley *et al.* 2017; Gruber and Hungerman 2008) allow the policy outcomes to differ by period and control group. Thus, I conducted the regressions of the following DiD form:

$$y_{l,t} = \beta_0 + \beta_1 \text{Policy}_{l,t-1} + \gamma X_{l,t-1} + \alpha_l + \alpha_t + \varepsilon_{l,t} \quad (1)$$

where l denotes the local location subscript, t denotes the time subscript, and Policy represents the treatment variables for renewable energy policies. In this regression, I also include time-varying controls denoted as X_{rt}. α_r and α_t are fixed variables for the local locations[1] and years, respectively.

I adopted one-year lag independent variables for all models. I calculated the Akaike Information Criterion (AIC) up to three lags using full models. The results of the AIC showed that models with a one year lag were the best in the solar and wind power cases. In addition, hierarchical regression models with AR(1) were adopted. The data had a two-level structure. As the utilities in a local location share the same local context, a single-level regression could not capture the variability within and between locational groups. To control for similarities within a local place, a two-level hierarchical linear model can be used to deal with the two-level structure of the dataset.

4.3 Dependent variables

The total solar (solar PV and concentrated solar) and wind power plant capacity was constructed as a dependent variable for measuring the level of incumbent utilities' investment in renewable energy technologies using the Bloomberg New Energy Finance (BNEF) database. I collected the first public announcements of plant investment in solar and wind farm projects by utilities, as these indicate the willingness of electric utilities to invest in sustainable energy sources and minimize the time lag between a corporate decision and actual plant operation. Electric utilities have developed their solar and wind farms globally; however, the total solar and wind power plant capacity was restricted to firms' headquarter countries and states (home market) cases because domestic policies may not influence their international plants. As a result, it does not allow us to distinguish direct and indirect effects for global plants.

4.4 Mediator

In this study, the competitive pressure served as the major driving force behind industry dynamics (Anderson and Tushman 2001). They are caused by an increase in renewable energy sources, and they measure how much incumbent utilities are threatened by the renewable power technology as the mediator that links government policies with electric utilities' power plant capacity.

I tested two constructs for competitive pressure. First, the ratio of electricity generation from local solar/wind plants was constructed to measure market pressure (namely, market share). The market share is a traditionally accepted variable in estimating the level of the technology emergence (Klepper 1996). The high market share of the alternative technology represents the high competitive pressure on incumbents. This information was obtained from the US Energy Information Administration (EIA).

Second, I also operationalized competitive pressure as the wind/solar plant density set equal to the number of wind/solar power plants normalized by electricity market size. Population density is a measurement commonly accepted by the industry life cycle literature (Agarwal *et al.* 2002; Anderson and Tushman 2001). I used the number of renewable power plants because they can increase public recognition, leading to pressure on electric utilities regardless of plant size. For example, even when retail companies install small-scaled solar panels on their shop roofs, public recognition rises due to the demonstration effect and media announcement. In addition, the plant density can supplement the renewable power market share variable as an alternative mediator. These data were taken from the BNEF database.

4.5 Independent and control variables

FiTs and RPSs are the main independent variables in this study. To measure the FiTs, I used the national tariff in $/kWh that the governments guaranteed each year for the electricity generated (Johnstone *et al.* 2010) from the largest onshore wind turbines and rooftop solar PV systems, the most common types of solar and wind power systems among heterogeneous FiT schemes and categories.

Constructing the RPS variable was more challenging. RPSs impose on electric utilities the requirement to generate a specific percentage of electricity from renewable energy sources at different points in time. Yin and Powers (2010) compared different RPS measurements and favored measuring the gap between the number of RPSs and the renewable generation ratio at the starting year of the RPS. Using their concept, I constructed the time-variant RPS variable by subtracting the renewable generation ratio from the nominal RPS number herein. In federal countries such as the USA and Canada, the RPS target and implementation year was often set at the state level. Thus, I included separate observations for each state in the RPS variable. The data on the two policies were obtained from multiple sources including the IEA Policies and Measures Databases, the European Renewable Energies Federation, and the DSIRE Database of State Incentives for Renewable & Efficiency. The renewable generation ratio was retrieved from the IEA and US EIA database.

Electric utility size was measured by using total assets to control for the effect of company size on firms' deployment activities. Earnings before Interest and Taxes (EBIT) was used to control for profitability. The total asset and EBIT data were obtained from Compustat. The public ownership of electric utilities determines the industrial structure of the electric utility market. I created a dummy variable coded 1 if the majority shareholder of a firm was the government and 0 otherwise, according to the Orbis database.

The entry regulations and vertical integration variables of the electric utility market were also introduced to estimate the level of market liberalization at the country level. They ranged from 0 to 6 and were retrieved from the OECD International Regulation Database. The higher the value of the two market liberalization indicators, the less likely new firms are to enter the market. However, data for the selected years in the USA, Russia, and Malaysia cases were missing from the OECD International Regulation Database. Thus, I constructed data by using the OECD International Regulation Database coding scheme after collecting supplementary data about domestic market liberalization. To control for market size and country characteristics, I introduced total electricity generation in GWh drawn from IEA and US EIA database and a GDP growth rate drawn from World Bank database.

In addition, I added a financial market freedom variable indicating banking efficiency, drawn from the Heritage Economic Freedom Database. It measures countries' level of access to financial resources. Yoshino and Taghizadeh-Hesary (2018) argued that access to financial resources is a key determinant of investment in the renewable energy sector because it has high risk and uncertainty.

Lastly, I controlled for other policy measures that may influence deployment activities in the solar and wind power sectors. While continuous measurements are ideal for policies, quantifying the level of investment and tax policy support may induce measurement biases because of the heterogeneous nature of policies (e.g., the distinctive tax systems across countries). Thus, I adopted binary variables coded 1 if a focal policy was introduced by using the IEA Policies and Measures Databases (Johnstone *et al.* 2010; Rodríguez *et al.* 2015).

All market price data were deflated to 2010 constant US dollars by using the GDP deflators provided by the World Bank database. The total wind/solar power capacity of electric utilities, assets, and total electricity generation were expressed in natural logarithms to improve their normality.

5. Empirical results

Table 1 presents the descriptive statistics and correlation matrix among the variables. This matrix does not show serious interrelated sets of independent variables that could have collinearity problems.

Table 2 shows the results of the mediation and DiD models for solar power plants. This is an unbalanced panel because of the several missing data points owing to the restructuring process of many electric utilities. In Models 1–5 of Table 2, the total capacity of the solar power plants installed by electric utilities is modeled as a function of the policy variables, mediators, and control variables.

Only the FiT policy effects in Table 2 are significant among the two policy variables, and the effects of the control variables are mixed. Model 1 presents the baseline model excluding the mediator variables. The coefficient of the FiT indicator is positive and significant, whereas that for the RPS policy variable is not significant.

Table 1. Summary statistics and correlations

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Total solar power capacity (ln GW)	0.16	0.79														
2. Solar market share (%)	0.04	0.09	0.10													
3. Plant density (# solar plants/electricity market size)	0.01	0.07	0.60	0.44												
4. Solar FiT ($/kWh)	0.08	0.22	0.36	0.30	0.35											
5. RPS	0.01	0.04	0.02	0.33	0.36	−0.10										
6. Size (ln Million USD)	10.34	0.88	0.17	0.12	0.13	0.19	−0.00									
7. EBIT (ln Million USD)	8.98	0.45	0.11	−0.04	0.08	0.13	0.01	0.29								
8. Public owned enterprises	0.20	0.40	−0.00	−0.15	−0.06	0.16	−0.13	0.15	0.10							
9. Entry regulation	1.24	1.32	−0.14	−0.18	−0.14	−0.21	−0.06	−0.08	−0.03	0.19						
10. Vertical integration	4.58	0.73	−0.09	0.01	−0.16	0.03	−0.18	0.00	0.00	0.34	0.34					
11. Electricity generation market (ln GWh)	12.34	0.93	0.07	0.30	0.02	0.17	−0.08	0.13	0.06	0.06	0.02	0.52				
12. GDP growth rate	2.78	1.84	0.02	−0.07	0.02	−0.10	0.00	−0.19	−0.06	0.07	−0.05	−0.24	−0.29			
13. Financial market freedom	67.62	18.61	−0.01	−0.13	0.06	−0.27	0.28	−0.06	−0.00	−0.29	−0.11	−0.60	−0.51	0.04		
14. Solar tax policy	0.41	0.49	−0.07	−0.14	−0.03	−0.15	0.21	0.08	0.01	−0.03	−0.06	−0.42	−0.31	0.09	0.46	
15. Solar investment policy	0.85	0.35	−0.27	0.07	−0.15	−0.07	0.11	0.10	0.01	−0.04	−0.05	−0.07	0.19	−0.20	0.21	0.33
Variable	Mean	S.D.	16	17	18	19	20	21	22	23	24	25	26	27	28	29
16. Total wind power capacity (ln GW)	1.61	2.55														
17. Wind market share (%)	0.90	1.69	0.56													
18. Plant density (# wind plants/electricity market size)	0.14	0.25	0.65	0.74												
19. Wind FiT ($/kWh)	0.01	0.03	0.51	0.58	0.48											
20. RPS	0.01	0.04	0.00	0.11	0.09	−0.11										
21. Size (ln Million USD)	10.34	0.88	0.20	0.10	0.08	0.20	−0.00									
22. EBIT (ln Million USD)	8.98	0.45	0.10	0.05	0.08	0.13	0.01	0.29								
23. Public owned enterprises	0.20	0.40	−0.02	−0.13	−0.07	0.19	−0.13	0.15	0.10							
24. Entry regulation	1.24	1.32	−0.31	−0.25	−0.32	−0.21	−0.06	−0.08	−0.03	0.19						
25. Vertical integration	4.58	0.73	−0.10	−0.16	−0.21	0.05	−0.18	0.00	0.00	0.34	0.34					
26. Electricity generation market(ln GWh)	12.34	0.93	0.10	0.07	0.00	0.17	−0.08	0.13	0.06	0.06	0.02	0.52				
27. GDP growth rate	2.78	1.84	−0.13	−0.06	−0.06	−0.11	0.00	−0.19	−0.06	0.07	−0.05	−0.24	−0.29			
28. Financial market freedom	67.62	18.61	−0.00	−0.04	−0.01	−0.29	0.28	−0.06	−0.00	−0.29	−0.11	−0.60	−0.51	0.04		
29. Wind tax policy	0.42	0.49	−0.03	−0.18	−0.09	−0.11	0.21	0.08	0.01	−0.04	−0.07	−0.41	−0.31	0.09	0.47	
30. Wind investment policy	0.86	0.34	−0.04	−0.21	−0.26	−0.08	0.10	0.10	0.00	−0.08	−0.11	−0.04	0.25	−0.22	0.19	0.31

Table 2. Results of incumbent utilities' home market investment: the total capacity of solar power plants

	Dependent variables at time $t+1$				
	(1)Total capacity	(2)Market share	(3)Plant density	(4)Total capacity	(5)Total capacity
Market share				−0.952	
				(0.675)	
Plant density					2.856***
					(0.471)
FiT	1.411***	0.076***	0.113***	1.458***	1.208***
	(0.230)	(0.027)	(0.038)	(0.232)	(0.223)
RPS	−0.198	−0.090	0.081	−0.336	−0.712
	(0.959)	(0.115)	(0.160)	(0.962)	(0.922)
Firm size	0.004	0.004	0.005	0.005	0.002
	(0.050)	(0.006)	(0.008)	(0.050)	(0.047)
EBIT	0.005	5.15e-05	0.002	0.008	0.002
	(0.042)	(0.004)	(0.006)	(0.042)	(0.043)
Public	−0.054	0.002	−0.005	−0.048	−0.057
owned enterprise	(0.273)	(0.044)	(0.062)	(0.272)	(0.229)
Entry	−0.029	−0.005	−0.002	−0.034	−0.022
Regulation	(0.035)	(0.004)	(0.005)	(0.035)	(0.034)
Vertical	0.105	−0.004	0.006	0.099	0.097
integration	(0.098)	(0.011)	(0.015)	(0.098)	(0.097)
Market size	1.394**	−0.019	0.122	1.267**	1.426***
	(0.573)	(0.069)	(0.095)	(0.579)	(0.550)
GDP growth	−0.008	0.003*	0.001	−0.005	−0.013
	(0.016)	(0.001)	(0.002)	(0.016)	(0.016)
Financial	0.004	0.002***	0.002**	0.004	0.001
market freedom	(0.004)	(0.000)	(0.001)	(0.004)	(0.004)
Tax policy	0.011	−0.001	−0.004	0.004	0.027
	(0.062)	(0.006)	(0.009)	(0.063)	(0.064)
Investment	−0.491***	0.008	0.045**	−0.502***	−0.555***
Policy	(0.140)	(0.016)	(0.022)	(0.140)	(0.138)
Constant	−17.80**	0.206	−1.700	−16.15**	−18.05**
	(7.471)	(0.905)	(1.253)	(7.548)	(7.170)
Year dummies	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes
Log likelihood	−327.5	695.9	535.4	−326.5	−312.9
Chi-square	211.7***	222.3***	176.3***	214.6***	308.8***
Observations	488	488	488	488	488

Standard errors in parentheses. *, **, ***: significant at the 10%, 5%, and 1% level, respectively.

Models 2 and 3 present the results of the mediation regression model including the two mediators. Model 2 incorporates the ratio of electricity generation from domestic solar plants as the mediator variable. Model 3 includes the number of solar plants normalized by total electricity generation as the mediator variable. The results show that the FiT policy variables are positive and significant, while the RPS policy variable is not significant. This result confirms that FiT policies are more effective than RPS policies in terms of the deployment of renewable energy, consistent with prior studies.

Models 4 and 5 re-estimate the coefficients after including the mediators. I add a market share mediator into Model 4 and a plant density mediator into Model 5. These models show the pressure effects from new technology emergence and direct policy incentive (regulatory) effects separately. The results of Models 4 and 5 indicate the presence of direct economic incentive policy effect, namely FiTs, supporting H1a. For the indirect effect, Model 4 indicates that the market share variable is not significant, while Model 5 shows that the plant density variable is significantly positive, concurring with the mediator models (Models 2 and 3), supporting H1b partly. It passed the Sobel test at the 5% level as well and thus we can measure the size of the direct and indirect effects of the FiT policies.

Models 6–10 of Table 3 examine the total capacity of the wind power plants invested by electric utilities as a function of the policy variables, mediators, and control variables. The model structure and variables are the same as in the solar power case. I find the possibility of competitive pressure and policy incentive effects driven by the FiT policy in the wind power plant sector in Model 6 (baseline model). In turn, a causal link between the FiT policy and mediators is revealed. This means that the FiT policy variables are positive and significant in Models 7 and 8. Lastly, the results of Models 9 and 10 show that the competitive pressure variables and the FiT variable are significantly associated with an increase in the total capacity of the wind power plants invested in by electric utilities. Sobel's test also indicates that mediation occurs at the 5% level; however, the RPS variable is not significant. These results support H1a and H1b.

Contrary to the solar case, I find a positive correlation between the FiT policy and market share mediator. Incumbents are also more capable of handling wind power plants requiring efficient operation skills so that they more respond to competitive pressure from wind power. It supports the H2a.

Some prior studies have found the positive effect of RPSs in deployment performance in contrast to the study results. This gap may

Table 3. Results of incumbent utilities' home market investment: the total capacity of wind power plants

	Dependent variables at time $t+1$				
	(6)Total capacity	(7)Market share	(8)Plant density	(9)Total capacity	(10)Total capacity
Market share				0.307***	
				(0.0959)	
Plant density					2.541***
					(0.582)
FiT	12.63***	8.118***	0.672***	10.44***	10.36***
	(2.977)	(1.480)	(0.208)	(3.044)	(2.986)
RPS	0.645	1.644*	0.073	0.737	0.647
	(1.921)	(0.942)	(0.132)	(1.905)	(1.890)
Firm size	0.130	0.059	0.004	0.117	0.119
	(0.105)	(0.054)	(0.007)	(0.104)	(0.103)
EBIT	0.015	0.016	0.002	0.007	0.009
	(0.078)	(0.036)	(0.005)	(0.079)	(0.078)
Public	−0.197	0.040	0.001	−0.244	−0.231
owned enterprise	(0.639)	(0.411)	(0.058)	(0.618)	(0.605)
Entry	0.162**	−0.011	0.005	0.175**	0.159**
Regulation	(0.070)	(0.034)	(0.004)	(0.070)	(0.069)
Vertical	−0.480**	0.081	−0.023*	−0.525***	−0.421**
Integration	(0.192)	(0.091)	(0.012)	(0.191)	(0.191)
Market size	−0.595	0.423	−0.042	−0.626	−0.342
	(1.145)	(0.565)	(0.079)	(1.135)	(1.128)
GDP growth	0.003	0.006	−0.001	0.004	0.003
	(0.030)	(0.014)	(0.002)	(0.030)	(0.030)
Financial	−0.022***	−0.001	−0.001	−0.023***	−0.022***
market freedom	(0.008)	(0.003)	(0.001)	(0.008)	(0.008)
Tax policy	−0.251**	−0.016	−0.002	−0.239**	−0.244**
	(0.118)	(0.054)	(0.007)	(0.118)	(0.118)
Investment	0.266	−0.160	0.004	0.350	0.277
Policy	(0.340)	(0.165)	(0.023)	(0.339)	(0.336)
Constant	10.60	−5.510	0.873	11.14	6.619
	(14.91)	(7.386)	(1.040)	(14.78)	(14.70)
Year dummies	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes
Log likelihood	−666.7	−349.9	603.5	−661.8	−657.8
Chi-square	283.4***	341.2***	357.6***	318.7***	344.5***
Observations	488	488	488	488	488

Standard errors in parentheses. *, **, ***: significant at the 10%, 5%, and 1% level, respectively.

stem from the use of different research samples. For example, Carley *et al.* (2017) included a variety of developing countries in their research sample and Yin and Powers (2010) restricted their samples to the USA. In contrast, this study contains global cases with a focus on advanced countries. The control group in this study shows a moderate increase in electricity generation from renewable energy in the DiD models on average so that the moderate effect of RPSs in developing countries and US states becomes statistically insignificant. When restricting the investigation to the US cases following Yin and Powers (2010), the estimate of RPSs in the mediator models for wind power becomes positive and significant at the 1% level. Although the local fixed variables and year dummies are included in Models 1–10, the results are not displayed to save space.

I have investigated incumbents' response to economic incentives and regulatory policies for renewable energy in the home market so far. Electric utilities adapt to the new market environment by establishing in local renewable power plants. However, at the same time, they diversify their global renewable power generation portfolio as a repositioning strategy to respond to policy-induced pressure at home. To test this argument, I operationalized the total solar and wind power plants owned by electric utilities out of the local areas and show that the differences in power plant capacity in non-local areas arise as a function of the one-year lagged competitive pressure and control variables in Table 4. Note that this table includes the number of major subsidiaries operating in non-local areas as an additional control for prior experience and strategic motivation of international expansion drawn from the US Federal Energy Regulatory Commission's Form 1 and the firm official websites. I added this variable without one year lag because a new subsidiary is likely to acquire existing renewable power facilities from other firms. I examined this variable with one year lag, but all results support the argument as well. It excludes the domestic policy variables, which do not influence incumbents' power capacity beyond their local areas. For this reason, we do not adopt the mediation model as prior models have.

Models 11–14 in Table 4 present the results of the total solar and power plants in non-local areas. They reveal that competitive pressure on the electric incumbents in local areas increases their capacity in wind power plants outside their home locations; however, we do not observe this positive effect in the solar power case. It indicates two findings. First, when incumbents are exposed to great pressure on their main business models in the

Table 4. Results of incumbent utilities' global renewable power generation portfolio: the total power plant capacity in non-local areas

	Total capacity at time $t+1$			
	Solar		Wind	
	(11) Non-local	(12) Non-local	(13) Non-local	(14) Non-local
Market share	−1.361**		0.430***	
	(0.571)		(0.101)	
Plant density		0.098		3.013***
		(0.436)		(0.628)
Non-local subsidiary	0.060	0.064	0.964***	0.980***
	(0.051)	(0.051)	(0.143)	(0.142)
Firm size	−0.000	−0.003	0.158	0.160
	(0.044)	(0.045)	(0.108)	(0.107)
EBIT	0.011	0.006	0.033	0.038
	(0.040)	(0.040)	(0.078)	(0.078)
Public owned enterprise	0.067	0.059	−0.554	−0.520
	(0.221)	(0.225)	(0.706)	(0.702)
Entry Regulation	0.001	0.009	−0.072	−0.088
	(0.032)	(0.032)	(0.070)	(0.070)
Vertical Integration	−0.012	−0.003	0.106	0.217
	(0.090)	(0.091)	(0.193)	(0.192)
Market size	−0.662	−0.511	0.889	1.193
	(0.515)	(0.516)	(1.157)	(1.153)
GDP growth	−0.016	−0.021	−0.013	−0.014
	(0.015)	(0.015)	(0.030)	(0.030)
Financial market freedom	−0.011***	−0.011***	0.001	0.003
	(0.003)	(0.003)	(0.008)	(0.008)
Constant	9.470	7.519	−12.77	−17.71
	(6.712)	(6.729)	(15.10)	(15.04)
Year dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Log likelihood	−283.1	−285.8	−679.5	−677.2
Chi-square	120.5***	112.4***	269.3***	277.6***
Observations	488	488	488	488

Standard errors in parentheses. *, **, ***: significant at the 10%, 5%, and 1% level, respectively.

home market, they endeavor to reposition their business by entering other global markets. It supports H2b. Second, when incumbents diversify their renewable power generation portfolio across countries, they prefer wind power plants to solar power plants. Solar power density does not increase incumbents' plant capacity in neighboring markets in contrast to their capacity in the home market. It supports H2a.

5.1 Robustness tests

Two additional analyses are conducted to test the robustness of the results. First, when I examined the incumbents' global renewable power plant capacity, I measured the total power plants in non-local areas. However, incumbent utilities sometimes do their business in the neighboring areas. In this case, establishing solar and wind power plants in the neighboring areas is not a geographical diversification strategy. To address this concern, I constructed the dependent variable as the solar and wind power plant capacity installed outside their continental areas. Several firms do their business out of the continental areas, but their proportion is small and inter-continental business units are usually separated from parent firms if their size is sufficiently large (e.g., Enersis in Chile owned by Italian firm ENEL). To save the space, I did not display the results, but they remain the same.

Second, I test whether the direct and indirect policy effects of FiTs and RPSs are robust when considering the possible endogeneity of the policy variables arising from, for example, the political power of stakeholders that may influence the policy measures according to their interests and strategies in the renewable energy market. I apply a two-stage least squares (2SLS) model to address this possible endogeneity.

In this model, I instrument the FiT and RPS policy variables by using the mean values of FiTs and RPSs implemented in the continent-year as an instrumental variable. For this analysis, I divide the sample into four continental groups, namely Europe (including Russia), Asia, North America, and South America. Policy convergence referring to policy diffusions across borders has been a topic of interest in the public policy studies. There is no prior empirical studies that covered all continents due to the lack of available data (Heichel *et al.* 2005), but they revealed that the geographical proximity was a key factor to policy convergence because they share similar geographical and institutional conditions (Radaelli 2000; Walker 1969). Policy convergence was also identified in a renewable energy policy domain (Heichel *et al.* 2005). In contrast, this instrument rarely correlates with utilities' local power plant capacity in renewable energy because they do not decide on local power plant capacity by considering the policies of neighboring markets. Further, group-mean values (e.g., industry-mean values) are commonly accepted instrumental variables in empirical research (Birhanu *et al.* 2016; Chang *et al.* 2016).

Table 5. 2SLS model results of incumbent utilities' home market investment: the total capacity of solar power plants

	Dependent variables at time $t+1$				
	(15)Total capacity	(16)Market share	(17)Plant density	(18)Total capacity	(19)Total capacity
Market share				−1.253*	
				(0.758)	
Plant density					3.230***
					(0.516)
FiT	2.708***	0.557***	0.614***	3.152***	1.807**
	(0.790)	(0.093)	(0.131)	(0.830)	(0.782)
RPS	0.312	0.042	0.229	0.253	−0.539
	(1.075)	(0.124)	(0.173)	(1.072)	(1.036)
Firm size	0.072	0.015	0.015	0.077	0.054
	(0.084)	(0.012)	(0.017)	(0.084)	(0.071)
EBIT	0.015	0.001	0.003	0.020	0.010
	(0.045)	(0.004)	(0.006)	(0.045)	(0.047)
Public	−0.072	−0.003	−0.007	−0.069	−0.058
owned enterprise	(0.342)	(0.061)	(0.096)	(0.340)	(0.269)
Entry	−0.006	0.000	0.005	−0.004	−0.014
regulation	(0.042)	(0.004)	(0.006)	(0.042)	(0.041)
Vertical	0.168	0.001	0.013	0.164	0.161
integration	(0.114)	(0.012)	(0.017)	(0.114)	(0.112)
Market size	1.792***	0.002	0.182*	1.611**	1.832***
	(0.660)	(0.075)	(0.106)	(0.668)	(0.635)
GDP growth	−0.023	0.003	−0.002	−0.015	−0.027
	(0.024)	(0.002)	(0.003)	(0.024)	(0.024)
Financial	0.002	0.002***	0.001**	0.003	−0.001
market freedom	(0.004)	(0.001)	(0.001)	(0.004)	(0.004)
Tax policy	−0.080	−0.020**	−0.021*	−0.106	−0.039
	(0.077)	(0.008)	(0.011)	(0.078)	(0.078)
Investment	−0.783***	0.008	0.069**	−0.806***	−0.891***
policy	(0.193)	(0.021)	(0.030)	(0.193)	(0.189)
Constant	−23.69***	−0.243	−2.688*	−21.43**	−23.78***
	(8.655)	(0.997)	(1.400)	(8.743)	(8.310)
Year dummies	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes
Log likelihood	−324.4	615.6	463.8	−323.1	−308.8
Chi-square	185.6***	283.2***	199.7***	190.3***	290.7***
Observations	438	438	438	438	438

Standard errors in parentheses. *, **, ***: significant at the 10%, 5%, and 1% level, respectively.

In the first stage of the 2SLS model, I regress the FiT and RPS variables on the lagged average FiTs and RPSs implemented in the continent-year and all the exogenous variables except the mediator variable because competitive pressure is induced by policy measures, but it does not cause them in the mediation models. For the RPSs, we need more than one year lag because the actual renewable generation used in the RPS construct takes 2–3 years to be realized after the planning stage. Thus, I set three year lags for the first stage of the RPS variable.

I then conduct post-estimation tests for instrument strength and the presence of endogeneity before the second-stage analysis. For instrument strength, I apply the conventional rule of thumb, indicating an appropriate instrumental variable if the F-statistics are more than 10 in the first stage (Staiger and Stock 1997) and find that all the instruments meet this condition. In case, the instrument strength test is conducted using one year lag for the RPS, and confirms that it does not meet the condition. I adopt the Durbin–Wu–Hausman test to examine the presence of endogeneity. I confirm that there is no endogeneity in the wind power baseline model, but the presence of endogeneity in the FiT of the solar power baseline model. Tables 5 presents the results of the solar power case in which endogeienty in the FiTs is concerned. I find that the arguments hold.

In addition, I tested panel unit root tests and cointegration tests for dependent and independent variables because they can lead to spurious regression results. I performed Augmented Dicky-Fuller tests in level up to three lags. While solar power capacity, solar FiT, and solar competitive pressure variables have unit roots in the case of the solar power, only wind competitive pressure variable contains unit roots in the case of the wind power. I performed unit root tests using differences and finds that they are I(2) for solar variables and I(1) for wind variables, indicating that the series are stationary in second differences for the solar case and in first differences for the wind case.

Then, I conducted the cointegration tests using the Westerlund method with up to three lags for both the solar and wind power cases. Various statistics mostly indicated that the null hypotheses were not rejected. This means that there is no cointegration among non-stationary variables and a spurious regression is of little concern in the models.

6. Interpretation and discussion

This study analyzes how both economic incentives (e.g., FiTs) and regulatory demand-side policies (e.g., RPSs) affect the investment of incumbents in the new technologies using the solar and wind power case. It is found that incumbent utilities under FiT policies invest more deeply in the diffusion of solar and wind power than those under RPS policies.

The economic incentive policy brings about two effects. The first is that such policies provide a new financial opportunity, even for incumbents by reducing financial risk. The second is the indirect competitive pressure effect. Economic incentive policy encourages the market competition and subsequently threatens incumbents' dominant position. In the real world, electric utilities face large challenges such as the decrease in electricity price and profit after the introduction of FiTs (Di Cosmo and Valeri 2014; Frondel *et al.* 2010). In addition, incumbents also find a chance of adopting new technologies when policy-induced competitive pressure is increasing because they can gain competitiveness by leveraging existing internal resources and customers under intensive competition (Cozzolino *et al.* 2018).

Policy-induced competitive pressure encourages incumbents to extend their business into other countries (Pettus *et al.* 2017). Basically, capturing external opportunities is a reaction to competitive pressure, but this gives also them an opportunity to reevaluate the value of the new technologies internally and helps firms rethink their business models and overcome organizational inertia (Kishna *et al.* 2017). The results show that increases in competitive pressure are associated with electric utilities' power plant capacity in non-local areas as a part of their repositioning. This finding implies that incumbents respond to competitive pressure with dual market strategies, namely adaptation in the home market and repositioning using the global market. It is a spillover effect of the domestic economic incentive policy that contributes to global diffusion of the sustainable technologies.

Policy-induced competitive pressure also induces incumbents to choose a specific technology strategy. While solar power is suitable for small-scale power systems, wind power is appropriate for large-scale power systems. The BNEF dataset verifies that the average solar farm is 19 MW compared with 116 MW for a wind farm. The results consistently show that incumbents more respond to competitive pressure driven by the wind power than the solar power because incumbents have know-how about large-scale power plant operation from their existing fossil-fuel power plants. Their existing competences drive them to choose a specific new technology.

In contrast, regulatory policies (e.g., RPSs) do not influence incumbents' investment in new technologies. Electric utilities cannot reject a request of independent power producers on connecting independent power producers' renewable power to their grid either. However, given that renewable energy sources are more expensive than traditional energy sources, someone has to bear the cost of generation from renewable energy sources under RPSs. This economic burden is likely to be shifted to independent and new power producers rather than electric utilities because new comers' political power is weaker (Schmalensee 2012). It implies that competitive pressure induced by regulatory policies is not severe for incumbents. Furthermore, the regulatory policy effect is weaker than the economic incentive effect because governments are unlikely to punish large incumbents even when they violate the regulations. Thus, large incumbents tend to ignore regulatory policies (Darnall *et al.*, 2010).

7. Conclusion

Recent studies on demand-side policies emphasize the policy effects on a firm behavior and direction of technological changes (Hoppmann *et al.* 2013; Wesseling and Edquist 2018). Hence, this study contributes to demand-side policy literature by analyzing the effects of the demand-side policies that shape the market environment to encourage the commitment of incumbents to new technologies (Weigelt and Shittu 2016) and examining incumbents' response to policy-induced competitive pressure with a focus on technology and market strategies.

Although prior work has simply evaluated policies based on the level and cost of diffusion of new technologies, this study expands the discussion by including other possible goals of demand-side policies such as the market environment for the participation of incumbents. This issue is important because, for the shift toward a more sustainable system to take place, actors can gain valuable resources and capabilities from incumbents at least in the early stage of new technologies (Choi *et al.* 2011; King and Tucci 2002; Kishna *et al.* 2017) and it is likely that incumbents will need to be engaged in the restructuring process other than being replaced by new entrants in sectors with natural monopolies.

It also enriches the discussion on diverse responses of incumbents to demand-side policies (Doh and Pearce 2004) by introducing two distinctive policies and comparing their effects on incumbents' investment in new technologies. Although incumbents with complementary assets have a more chance of investing in the new technologies (Hill and Rothaermel 2003; Jiang *et al.* 2011), complementary assets do not guarantee their investment. It is contingent to the market environment and demand-side policies. Therefore, it contributes to diminishing a research gap between the industry life cycle and demand-side policy studies (Carroll and Khessina 2005; Weigelt and Shittu 2016).

This study has practical implications. For manages in incumbents, it offers insights when they choose technology and market strategies under policy-induced competitive pressure. They need to appropriate technology and market strategies that best uses their existing competences and complementary assets. In detail, they can utilize policy-induced competition to reposition themselves in the market. Incumbents are likely to encounter internal resistance to new technologies, which they need to overcome. Threat and competition driven by demand-side policies can enable them to invest in new technologies for the domestic market as well as extend their geographical locations. In this process, incumbents can leverage their existing competencies and this can reinforce their market repositioning even further.

For public policymakers, it shows that economic incentive approaches may encourage the investment of incumbents in the diffusion of sustainable technologies, compared with regulatory policies, by increasing competitive pressure. Regulatory approaches may also offer opportunities to new entrants; however, they are limited by incumbents. Although prior works have evaluated policies based on the level and cost of diffusion, this study expands the discussion by including other possible demand-side policy mechanisms such as shaping the market environment for the investment of incumbents in the downstream industries. Some concerns have been raised about the unintended spillover effects of domestic demand-side policies across borders when allowing international players to enter their home market (Choi and Anadón 2014; Peters *et al.* 2012). However, this study shows the probability that domestic demand-side policies can encourage corporate entrepreneurship of domestic firms, leading to their investment in a global market by increasing the home market competition. Policy makers in the public sector should consider these effects of two demand-side policies associated with incumbents' investment when designing policy schemes because both policies have distinctive effects on incumbents' investment behavior.

7.1 Limitations and future research

This study contributes to theory development and practical implications, but there are also some limitations. First, demand-side policies aim at early market creation and diffusion of new technologies. However, they may have other policy goals. For example, some prior studies have investigated a relationship between demand-side policies and technological innovations and manufacturing facility investment in the upstream industry (Choi and Anadón 2014; Peters *et al.* 2012; Taghizadeh-Hesary *et al.* 2018). Along this line of thought, we can explore incumbents' investment in technological innovations and manufacturing in response to demand-side policies in future research. The current study shows that regulatory policies (e.g., RPSs) have less impact on deployment performance, but future research may offer new insight into regulatory policies for new technologies as Peters *et al.* (2012) highlighted the importance of regulatory policies for innovation outcomes.

Second, I restricted the investigation to the years up until 2008 because this period is the emerging phase of solar and wind power and also to minimize the impact of the 2008 global financial crisis on post-2009 deployment activities. However, future research needs to examine the post-2009 period because it enables us to capture another interesting phenomenon in the renewable energy sector.

Note

1. Local locations are defined as jurisdictional boundaries where consistent FiT and RPS measures are applied. In general, they are countries, with the exception of the USA and Canada, where each state is a local location.

Acknowledgements

I am grateful for insightful feedback from participants at a number of conferences and seminars. I also would like to thank Laura Díaz Anadón and Henry Lee for their valuable comments on an earlier version of this article.

Funding

This work was supported by the Science, Technology, and Public Policy program at the Belfer Center for Science and International Affairs at the Kennedy School, a gift from Shell, and a grant from BP IL on 'Energy, Climate, and Security Policy' Incumbents' Response to Demand Side Policies: The Case of Solar and Wind Power Sectors.

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