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What explains the selection of policy tools and instrument mixes in renewable energy policy

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Abstract

Since the Paris agreement stipulates limiting GHG emissions, much effort has been made to increase national consumption of renewable energy (RE). However, the adoption of policy instruments supporting RE varies depending on government capacity and instrument constituencies. This study examines how the following determinants, the policy and fiscal capacity of government, and the preferences of instrument constituencies affect the adoption rates of instruments. The empirical findings confirm that to achieve RE policy goals, governments should enhance their capacities required for specific instruments. Moreover, the preferences of civil society and interest groups also play a significant role in the policy adoption.

Key words

Policy Instrument, Policy Mix, Policy Instrument Adoption, Renewable Energy

1 Introduction

On 12 December 2015, representatives of 195 countries agreed to adopt Paris Agreement that would bring more powerful and extensive measures of greenhouse gas reduction compare to the Kyoto Protocol. Under this stringent measure, most countries around the world now share the goal of reducing GHG emission to prevent. As a result, mitigating climate change is now one of the most important objectives in national energy policy for many countries. The policy goal to achieve this objective is clear; these countries must rapidly expand the proportion of electricity generated from renewable energy (RE) sources in energy supply systems. What is not so simple and challenging, is RE policy lies at the intersection of different policy areas such as industry, energy, environment and sustainable development. In other words, many competing interests from diverse stakeholders influence RE policy. Therefore, achieving policy goal requires government to effectively mediate diverse and conflicting interests.

As a consequence, nearly all countries around the world have policies supporting RE power generations (REN21, 2016), and governments continue to adopt and revise a variety of RE policy tools. In this context, governments have strongly intervened in the renewable energy sector through various policy tools, and much research has been focused on the effects of renewable energy policy tools.

To understand RE policy tools, we must first understand mixes of policy instrument inside the policy tools. In practice, most policy tools are not comprised of single instruments but of several instruments to address complex policy situations. Nevertheless, much of prior researchers included limited sets of policy tools or instruments like FIT or RPS. While they have been regarded as successful instruments to promote renewable energy growth in most advanced countries, influences from other instruments have been neglected. Relatively less effort has been placed on other policy instruments and their instrument mixes. Most of all, there have been few studies on how different policy instruments are selected and combined in the

renewable energy area. In addition, prior researchers have generally focused on successful cases of industrialized countries. Consequently, there are clear limitations in extending these research implications to underdeveloped countries.

Against this background, this research aims to understand what factors affect countries from selecting different policy instruments for renewable energy. To achieve this end, I will conduct panel data analysis of 55 countries from 2004 to 2012. Since most RE policy tools can be differentiated by the extent of government intervention, I categorize an adoption rate of substantive policy instruments into two policy tools of regulation and economic incentive as depedent variables. For independent variables, I use government capabilities and instrument constitutencies which affect the selection of RE policy instruments. In order to develop valid policy implications around the world, the data covers from advanced countries to developing and underdeveloped countries in Asia and Africa.

This paper is structured as follows: Section 2 discusses the theoretical backgrounds of policy instrument choice and Section 3 introduces the method and data for analysis. Section 4 presents the analytical results and discussion, and Section 5 suggests conclusions and policy implications.

2 Theoretical backgrounds

2.1 Renewable energy policy tools

Government use policy tools to resolve a discrepancy between the policy goals and the current status quo (Stone, 2012). To achieve various policy goals, governments should carefully select appropriate policy tools. Specifically, policy solutions for social problems are composed of policy tools or instruments. In many studies, the term policy tools and policy instruments have been used without distinction.

However, this study uses a distinction between policy tools and policy instruments, with the former encompassing the latter. Accordingly, policy tools are broader and upper category of

policy instruments. For example, policy tools can be categorized by degree of public authorities' intervention (i.e. regulatory instruments, economic instruments, information etc.). Policy instruments are more like substantial measures taken by public authorities. In this regards, a brief overview of policy tools and instruments for energy policy is presented in Table 1. As shown below on the table, there exist several kinds of policy tools in energy policy sector, and substantial policy instruments are grouped in the policy tools by their properties.

<Table 1>. Policy tools and instruments for energy policy

Policy Tool	**Policy Instrument**
Regulatory Instruments	Auditing Codes and standards Monitoring schemes Obligation schemes Other mandatory requirements
Economic Instruments	Direct Investment Fiscal/financial incentives Market-based instruments
Information and Education	Advice/aid in implementation Information provision Performance label Professional training and qualification
Policy Support	Institutional creation Strategic planning
Research, Development and Deployment(RD&D)	Demonstration projects Research programmes
Voluntary approaches	Negotiated agreements Public voluntary schemes Unilateral commitments

Source: IEA(2013), Energy Efficiency Policy and Measurement Database

Comparing with energy policy, renewable energy policy tools have similar categories and policy instruments subsets. Among these policy tools, most widely preferred ones in the renewable energy sector are regulation and economic instruments (Gunningham, 2014).

In general, regulations are formulated in rules or directives which mandate policy target groups to act in accordance with the contents of these rules or directives (Vedung, 2007: 31). Thus, the

receivers of regulation should comply with regulations. If they violate the regulations, they may get a penalty for non-compliance.

On the other hands, economic instruments involve handing out or thetaking away of material resources in government to induce the policy target groups' behavior (Vedung, 2007: 32). So, the addressees of economic instruments are not obligated to take them and are guaranteed freedom of choice about RE generation. That is, the different levels of government's intervention make principal differences between regulations and economic incentives. For more explanations for RE instruments, the following section discusses the most influential types of policy tools-regulation and economic incentives, then their substantive policy instruments.

2.1.1 Regulatory instruments

In many countries, the position of generation from RE resources have been a latecomer which should compete with traditional energy resources in national energy supply system. RE generators have to invest for the installation of generating units to enter the existing energy market. Also, the enormous costs of R&D impose a heavy burden on investors of RE, since most of RE technologies remain initial stages in the developmental process. Yet the benefits from investments remain uncertain. Consequently, these extra costs influence a price range of RE and weaken its competitiveness. To solve this problem, governments have been intervened market to enforce RE generation with their regulations. For example, the overall aim of FIT is to provide cost-based compensation and stable revenue flow through long-term contracts (Gunningham, 2014: 14). Therefore, governments have been strongly intervened energy markets to promote RE through regulations.

If regulation is properly and constantly enforced by the government, it gives high dependability and predictability to RE generators. In spite of these virtues, regulatory measures sometimes confront critics that they are less flexible and less efficient than economic incentives.

However, the relative effectiveness and efficiency of regulatory instrument would vary in practice since they depend on the characteristics of the policy target groups and the capacity of the state (Gunningham, 2014: 12)

In 2004, regulatory instruments were adopted by 42 countries, and more than half of them enacted only one instrument (REN21, 2004). The number of countries having any kind of regulatory instruments has been increased in 2013 (89 countries) almost twice as much as the number in 2004 (REN21, 2013). Most of the countries enacted only 1~2 instruments, while Italy as national level and the United States as sub-national level had all the regulatory instruments. Among various regulatory instruments, FIT and RPS are the most widely adopted ones. In 2013, 71 countries (also 28 subnational levels) had adopted FIT, and RPS were in place in 22 countries (also 54 subnational levels) (REN21, 2013). Table 1 presents the details of the regulatory instrument for RE.

<Table 2>. Various types of regulatory instruments.

Regulatory Instrument	Description
①FIT(Feed-in tariff), premium payment	A policy that typically guarantees renewable generators specified payments per unit over a fixed period. FIT policies also may establish regulations by which generators can interconnect and sell power to the grid.
②Electric utility quota obligation/RPS	An obligation placed by a government on a utility company, group of companies or consumers to provide or use a predetermined minimum targeted renewable share of installed capacity, or of electricity or heat generated or sold. A penalty may or may not exist for non-compliance.
③Net metering	A regulated arrangement in which utility customers with on-site electricity generators can receive credits for excess generation, which can be applied to offset consumption in other billing periods. Under net metering, customers typically receive credit at the level of the retail electricity price. Under net billing, customers typically receive credit for excess power at a rate that is lower than the retail electricity price.
④Tradable REC	A certificate awarded to certify the generation of one unit of renewable energy. In systems based on RECs, certificates can be accumulated to meet renewable energy obligations and also provide a tool for trading among consumers and/or producers. They also are a means of enabling purchases of voluntary green energy.

Sources: REN21, Renewables 2016 Global Status Report

2.1.2 Economic instruments

Comparing with fossil fuel generation, relatively high investment-related costs of RE lead energy generators to high funding requirements (Del Rio & Mir-Artigues, 2014: 288).

For this reason, there is a need for reducing RE generators' financial burden to achieve RE policy goals. Economic incentives can encourage deployments of RE because they provide full (or partial) consumption or production cost to reduce the burden of investment (Polzin et al., 2015)

As we have seen earlier, the incentive is different from regulation since its appliance depends on the choice of RE generators. Rather, utilization of economic incentives helps the government to achieve RE policy goals by giving more autonomy and flexibility to energy generators and consumers as to how they achieve resource productivity (Gunningham, 2014). Economic incentives also tend to be more cost-efficient than regulatory instruments which requires extra costs for monitoring and enforcing. Given their advantages over regulation, economic incentives also have their own limitations. If contents & levels of economic incentives are not adequate to overcome high risk and uncertainty issues of RE investments, their effectiveness would be lower than expected.

There are many types of economic instruments that might be enacted for RE policy goals. Two main instruments of economic incentive are tax instruments and subsidies. The former can be important in start-up periods, where up-front costs are high, while long-term benefits remain uncertain. And the latter prevents the internalization of externalities, and for this reason, they are criticized and opposed as a drain on public revenue (Gunningham, 2012: 8). However, when designed and targeted properly, subsidies can promote energy efficiency of generation from renewable energy resources (IPCC, 2011).

In 2004, 42 countries adopted some kind of economic incentives for RE, and more than half of them (25 countries) had only 1~2 incentive instruments (REN21, 2004). As the number of

countries has increased constantly, 99 countries enacted more than one economic incentive in 2013 (REN21, 2013). Table 2 presents the details of economic incentive instruments for RE.

<Table 3>. Various types of economic incentives

Economic Incentive	Description
①Capital subsidy, grant or rebate	A subsidy that covers a share of the upfront capital cost of an asset (such as a solar water heater).
②Investment or production tax credits	Investment tax credit is a fiscal incentive that allows investments in renewable energy to fully or partially credited against the tax obligations or income of a project developer, industry, building owner, etc. Also, production tax credit is a tax incentive that provides the investor or owner of a qualifying property or facility with a tax credit based on the amount of renewable energy (electricity, heat or biofuel generated by that facility.
③Reductions in Sales, energy, CO_2, VAT, or other taxes	Reducing the whole or partial sales taxes, energy taxes, CO_2 taxes, VAT or other taxes
④Energy production payment	Providing payment for the production of Renewable Energy
⑤Public Investment, loans, or grants	Public support for which a financial return is expected (loans, equity) or financial liability is incurred (guarantee)

Sources: REN21, Renewables 2016 Global Status Report

As shown above, regulatory instruments and economic incentives are set of different policy instruments. Moreover, policy instruments such as FIT and RPS inside the regulation category may differ regarding their substantive designs. Despite their differences, this study focuses on their similarities.

Specific contents of each policy instruments are changing because of dynamic policy environments. Thus, a certain policy instrument in one country is not exactly the same one in another country. The same logic can be applied also to the time dimension. However, those instruments can be categorized by their attributes for multiple comparisons across time and country.

Also, this study investigates the dynamics of selecting RE policy tools. The selecting mechanism of governments can be divided by their intention and the resources. Derived from the previous discussion, regulatory instruments and economic incentives can be comprised of

several substantive instruments which share the common attributes as regulation or economic incentive. This is the reason for using combined dependent variables, putting regulatory instruments in one basket, and economic incentives in another.

2.2 Renewable energy policy mix

In the literature about environmental policy mixes, Gunningham and Sinclair (1999) have suggested that all policy instruments have their own strengths and weakness, and none are sufficient approach for every environmental problem in complex contexts. For instance, in RE policy areas, while regulatory instruments may trigger investments by providing a stable support for markets, economic incentives may further encourage investments by reducing the financial costs directly (Del Rio & Mir-Artigues, 2014: 288).

In the large majority of circumstances (though certainly not all), a mix of instruments is required to achieve multiple policy goals. Therefore, the term policy mix is used in many studies in various research fields. In a broad sense, policy mix is defined as the combination of several policy instruments. However, the details of the term in the literature vary (Foxon & Pearson, 2008; Kern & Howlett, 2008; Lehmann, 2012). As derived in the discussion above, the term policy tools and policy instruments are not used interchangeably in this study. Instead of the policy mix, I focus on the mix of policy instruments as a part of the overarching policy mix.

2.3. Choices of Renewable Energy Policy Instruments

2.3.1. Literature review

Although I consider the renewable energy policy instruments have their own characteristics, there are only limited number of studies that examine the dynamics of renewable energy instruments choices in the government. This lack of analysis is due to the fact that almost all

countries which enacted renewable energy policies have more than just one type of instruments (Del Rio & Mir-Artigues, 2014: 287). Furthermore, the underlying dynamics of policy instrument selection are harder to explain in general (Schaffer, & Bernauer, 2014: 15). These could be a research barriers which restrict researchers conducting empirical comparative studies of countries (Jenner, et al., 2012; Marques et al., 2010). To solve this problem, a review of the previous literatures on the dynamics of policy adoption using empirical analysis is essential.

To measure the adoption of various policy instruments as dependent variables, Vachon & Menz(2006) has utilized dummy variables for adoption of each policy instrument (i.e. RPS, net metering rules, public benefits funds, and generation disclosure rules). On the other hand, others have utilized combined dependent variables for several instruments (i.e. FIT & RPS (Jenner et al., 2012), FIT of Green certificate scheme (Schaffer & Bernauer, 2014))

Moreover, previous literatures have taken different approaches about underlying dynamics in the likelihood to adopt RE policy. First, potential influence on policy instruments choice could be categorized by related policy interests such as social, political and economic interests (Vachon & Menz, 2006). The analytic results suggest that social interests which include the level of income are positively linked to the adoption of RE policies. On the contrary, there is no significant influence from economic interests on the adoption of RE policy, except for the positive link between the proportion of electricity generated from fossil fuels and the adoption of RPS.

Second, Jenner, et al. (2012) test the hypotheses derived from private interest theory and public interest theory by analyzing the EU27 sample. Private interest theory has assumed that social groups have their own policy preferences and try to influence RE policymaking according to their preferences. Meanwhile, public interest theory assumes that policymakers have interests in helping to produce public goods such as sustainable development or clean air.

By using combined dependent variable, the measurement range of policy adoption was extended from RPS to FIT. The analytic results have supported hypotheses from private interest theory about the relations between the existence of lobby groups and RE policy adoption. A solar energy association has a significant positive effect on the adoption of the regulation. On the other side, a proxy for utilities' market power shows a negative influence.

Finally, Schaffer and Bernauer(2014) have used combined dependent variables for the adoption of FIT or green certificate schemes. Among the explanatory variables from domestic driving forces, the characteristics of existing energy supply system are particularly noteworthy. Interestingly, as they had expected to show a negative impact on adopting regulations, the observed effects have been significant in the opposite direction. That is, a high share of fossil and nuclear energy in the national energy supply increase the likelihood of country adopting RE policies.

The authors suggested that the result was drawn from the propensity of their sample. The heavy pressures from meeting the climate policy targets or reducing dependency on imported fossil fuel have made some countries deploy RE promoting policies. Also, unlike their expectations that nuclear energy is a substitution for renewables, some countries may treat nuclear energy and RE as complements to reduce fossil fuel generation. In the same contexts, the unexpected positive relationship between CO_2 intensity and policy adoption could result from the country's propensity to take steps towards reducing energy inefficiency. On the other hand, the income levels (GDP per capita) have shown a positive influence on policy adoption. Major findings from previous studies discussed above are presented in Table 4.[1]

[1] The variables used in the previous studies are presented in Appendix 1.

<Table 4> The analytical results of selected previous studies

	Vachon & Menz (2006)			Jenner et al. (2012)	Schaffer & Bernauer (2014)
Dependent Variables	Regulation		Incentive	Regulation (FIT or RPS)	Regulation (FIT of GCS)
	RPS	Net metering	Public benefit funds		
Explanatory Variables	Economic Interests: Electricity from fossil fuels (+)	-	-	Market power of utilities on state electricity market (-) Years of existence of a state chapter of the International Solar Energy Association (+)	Electricity from fossil fuels (+) Electricity from nuclear (+) CO_2 intensity of the economy (+)
	Social Interests (+)	Social Interests (+)	-	-	GDPperCapita (+)

Despite their contribution to the research of policy adoption, those literature suffer from several limitations. First, most of these studies used data from a few developed countries. For example, they either concentrate on U.S. States (Vachon and Menz, 2006), or on EU countries (Jenner et al., 2012). Thus, their contribution is limited to explaining policy adoptions of those developed countries. In addition, their research models may not enough to adequately capture the dynamics of policy adoption in terms of measurement. And, there is no scholarly consensus on the optimal RE policy mix for every country (Foxon and Pearson, 2007). For these reasons, I need to outline a proper theoretical framework for RE policy instruments adoption based on the theories and factors discussed in the previous studies.

2.3.2. A model of policy instrument choice

Selection of policy instrument is a complex matter influenced by many factors surrounding policy process. (Howlett et al, 2009:172). In a theoretical sense, any RE instrument may achieve given policy goal of promoting RE generation. In practice, different instruments could lead to different consequences in some contexts (Howlett, 2005). Since different instruments have

varying degrees of impacts depend on their appropriateness for a particular policy environment. Therefore, finding out various factors influencing the govermnet's selection should consider the characteristics of policy tools.

To answer the question such as "what explains the selection of particular policy mixes by government?", Howlett(2005) has suggested that there is a general pattern of choices on the basis of intersection which includes a small number of factors.

As derived in the previous studies concerning the dynamics of policy choice, policy process includes not only the actors involved but the institutional context (Lemaire, 2007: 61). Following a substantive-instrument choice model suggested by Howlett et al. (2009), the independent variables which affect instrument choices in most studies could be divided into two interlinked factors. Among these variables, one is a level of state capacity to affect societal actors. And the other is a complexity of policy subsystem which is comprised of actors that governments must affect through policy. In addition, their expected relationship can explain the chosen type of instrument . For instance, if the government has a high level of capacity and the policy subsystem in specific policy sector is complex, subsidy or market instruments can be used effectively. By comparison, a government with limited capacity but faces a complex subsystem would tend to utilize regulatory instruments.

In practice, there are several policy actors who want to influence the selection and implementation of RE policy tools with their own interests. This complex policy environments would require specific policy capacities to mediate these diverse interests during policy process. (Mez & Midttun, 2001). Nevertheless, the details of capacities needed for specific RE policy has been rarely studied. For instance, Carley(2009) measured policy capacity of the related agency with numbers of civil servants and suggested this could have a positive influence on the increase of promotion rate of RE. Considering these limitations of previous studies, this study

assumes that the required capacity of government could be different depends on the characteristics of policy tools.

To ensure efficiency of policy instruments, a government and related agencies should have a proper capacity to face complex policy environments (Howlett, Ramesh & Perl, 2009). For this reason, the government should consider their policy capacity as a precondition before the selection of policy instruments. Also, the efficiency of a policy can be related to low levels of financial costs. Therefore, an ability of the government to expense the required resources is also a critical factor in the selection of policy instruments. If a fiscal capacity of government is low, the higher costs of economic incentive compared with regulation could lead to an extra burden.

Besides the efficiency of policy instruments, legitimacy is another critical factor for policy adoption. Since RE policy lies on the intersection of different policy areas, there exist several policy actors with different interests. These policy actors may have cooperated or competed with others to gain the legitimacy of given policy instruments that they wish to enact. As derived in the substantive-instrument choice model, the attributes of policy subsystem have been considered as a determinant of the policy instrument adoption. This aspect needs to be further discussed because the definition of the term policy subsystem means a set of actors involved in dealing with a certain policy problem (Sabatier, 1987). In policy subsystem approach, the existence of certain policy subsystem defines a particular policy area. However, in practice, there may be disagreements within a policy subsystem about suitable policy solutions for the given policy problems. Thus, the limitation of policy subsystem approach lies in the poor understanding of who has been involved in making policy solutions and what is involved in this task (Beland & Howlett, 2016: 396).

In order to better grasp the dynamics of policy adoption, Voß and Simons (2014) have formulated the concept of an “instrument constituency” as a subsystem component. Their research focus is on the preferences of instrument constituency for policy solutions or

instruments (Voß and Simons, 2014). In this regards, instrument constituency is defined as a specific kind of collective actors, which is formulated around particular instruments. Based on the discussion above, this study considers the capacities needed for RE policy and the preferences of instrument constituency can influence the adoption of regulatory and/or incentive instruments of RE policy tools.

<Table 5>. A model of renewable energy instrument choice

Type of RE Instruments	Capacities needed for RE policy	Preferences of Instrument Constituency	
		Supporting RE Policy	Opposing RE Policy
Regulatory Instruments	Policy Capacity	Agree to adopt more regulatory instruments	Oppose to adopt more regulatory instruments
Economic Instruments	Fiscal Capacity	Agree to adopt more Economic incentive instruments	Oppose to adopt more economic incentive instruments

2.4 Research hypotheses

As discussed above, policy capacity of government is required for the effectiveness of policy instruments. For example, regulatory instruments need more personnel costs to ensure changes of target group behavior. In RE regulations, enforcing regulation requires monitoring costs to ensure whether policy target group comply with their obligations. If there exist any violation of the regulation, regulatory authorities may spend extra efforts and costs to alter the behavior.

H1: Countries with high policy capacity are more likely to adopt regulatory instruments of RE policy tools.

On the contrary, implementing economic incentive requires relatively small personnel costs since the policy targets who wish to get some fiscal supports would join the process by

themselves. Hence, the most important capacity needed for economic incentives is funding. Fiscal capacity of government has been regarded as determinants of stronger environmental friendly policies such as RE policy because policy adoption and implementation cost money (Ringquist, 1994; Vachon and Menz, 2006; Stadelmann and Castro, 2014). Moreover, in most of the countries, economic incentives per se cost a lot of government's budget. In conclusion, we expect a positive relationship especially in the case of policies that provide subsidies for RE, because they will require a government with sufficient fiscal capacity. Without securing the proper amount of budget, economic incentives cannot be maintained.

H2: Countries with high financial capacity are more likely to adopt economic incentive instruments of RE policy tools

Environmental preferences of society have been also regarded as one of the determinants of environmental policy adoption (Vachon and Menz, 2006; Stadelmann and Castro, 2014). If a society cares about the environment, a government would be expected to adopt policies supporting environmental protection. Hence the preference of society matters in the policy process. The Environmental Kuznets Curve (EKC) argument assumes a trade-off between economic growth and environmental protection (Dinda, 2004). Thus, following the EKC argument, societies with higher income levels tend to adopt more RE policy instruments than poor societies which prioritize economic growth over environmental protection. In terms of the transaction costs, when income levels of a society have reached to certain levels, the society members would have a higher standard of living and put more focus on the upper values like an environmental protection (Grossman & Krueger, 1995; Schaffer & Bernauer, 2014). Therefore, citizens desiring higher standards of living may prefer RE instruments in advanced countries with higher GDP per capita.

H3: Countries with high-income levels are more likely to adopt regulatory and/or incentive instruments of RE policy tools

With the current transition to the climate change mitigating paradigm, sustainable development has been an important issue directly connected with each country's energy plans and related policies. To achieve GHG emission reduction target, there has been a growing recommendation for energy revolution (IEA, 2008: 41). The higher CO_2 emission of the country may lead to the higher social concerns about climate change, and eventually, this could increase the RE investment (Marques et al., 2010). That is, societies with higher CO_2 emissions tend to have more interest in coping with climate change, and this interest would positively affect RE development (Sadorsky, 2009; Menyah & Wolde-Rufael, 2010; Salim & Rafiq, 2012). Therefore, CO_2 emission can be used as a proxy reflecting society's interests in sustainable development, which have a positive influence on the adoption of RE policy tools.

H4: Countries with high CO_2 emission are more likely to adopt regulatory and/or incentive instruments of RE policy tools

Depends on the characteristics of a country's energy supply system, opportunity costs of promoting RE generation varies, because the strong expansion of RE would reduce profits from prior investments of conventional energy generators relying on fossil fuels and nuclear energy (Jenner et al., 2012; Schaffer & Bernauer, 2014). To be specific, growing shares of renewable energy in the national energy supply system may lessen existing shares of conventional energies. In addition, nuclear energy and renewable energy are both regarded as substitutes for fossil energy. Considering these competitive relationships, conventional energy generators are unlikely to support the promotion policy for RE. Hence, they would interrupt the adoption of

RE policy through their powerful lobby groups.

H5: Countries with a large fossil fuel share in national energy supply system are less likely to adopt regulatory and/or incentive instruments of RE policy tools

H6: Countries with a large nuclear share in national energy supply system are less likely to adopt regulatory and/or incentive instruments of RE policy tools

3. Methods and data

3.1. Research design

The empirical analysis of policy adoption is not a simple task, as shown above. To test research hypotheses empirically, I need to take several steps to gather country-year data. Since investigating the dynamics of selection requires a longitudinal research design like most of the previous empirical studies (Vachon and Menz, 2006; Jenner et al., 2012; Schaffer and Bernauer, 2014).

For empirical analysis, I use data from 55 countries that have already adopted one of the instruments in either regulation or economic incentives on 2004-2012. [23] Adding underdeveloped and developing countries to expand the sample may enable researchers to widen understanding in RE policy adoption and allow for more practical implications for policymakers. The time period of this study is limited from 2004 to 2012 due to the availability of data. Also, since policy instruments do not exhibit an immediate effect on the policy process, we add a time lag for one year in the dependent variables (2005~2013).

[2] The names of countries are presented in Appendix 2.

[3] Cases with missing values were removed.

3.2. Data

Data was collected from several independent sources (see Table 6 for details). I investigate the influence of the state capacity and instrument constituencies on the selection of two RE policy instrument mixes. Most indicators have been drawn from previous studies analyzing RE policies, except for the dependent variables. I structured the dependent variables according to the categories of RE instruments and applied additional processing. Two different policy mixes as dependent variables have their own subsets of policy instruments. The detailed explanation for measurement is presented below. Also, some of the independent variables such as GDP per capita, CO_2 emission are log- transformed to correct for the skewness.

Following the hypotheses presented above, I expect to see a positive influence on multiple instruments mix for every independent variable except for the influences from instrument constituencies of another energy sectors.

3.2.1. Dependent variables

This study uses the policy instrument mix as dependent variables. Measurement problem in these variables comes from the fact that I only have quantitative information on the set of RE policy instruments. Thus, I collect the information from policy landscape presented in Global Status Report by REN21. Considering the qualitative policy instruments information of the REN21 data, I have taken few steps to make dependent variables for regulatory instruments mix and incentive instruments mix.

Based on the RE policy categorization by REN21, I divide RE policy instruments into two categories: regulation and economic incentive. Although their details are different, instruments in each policy tools share some common attributes. For instance, governments make direct intervention to energy market through regulatory instruments. On the other hand, they induce private investors' decision with economic instruments.

And then, I retrieve each country's information on the adoption of each policy instruments. For each country and year, I assign value 1 for each policy instruments in national level and value 0.5 for province/sub-national level. The final measure of instrument mix is given by the percentage of the counts as a cumulative number of enacted policy instruments in each instrument category. These two variables take the value of "100" if the country had been adopted all the instruments in each instrument category and the value "0" if it had not been adopted any instruments.

According to the previous studies, the underlying assumption of using the cumulative numbers of active policies per year is that the more policy instruments are the better option for achieving policy goals (Johnstone et al. 2010; Marques and Fuinhas, 2012; Aguirre and Ibikunle, 2014). This measurement allows comparing the different policy experience of several countries at the same model, and also help to differentiate the effects of the policy mix.

3.2.2. Independent variables

① Government capacity

The capacity of government is a complex notion which can be modeled or measured differently by researchers or their research objectives. Above all, it is hard to measure the specific capacity of given RE policy. Since this study conducts a comparative analysis of several countries, I consider the overall government effectiveness in the policy process and fiscal condition of the government as proxies for capacity.

The former is measured by the composite indicators which have been presented in the Worldwide Governance Index developed by World Bank. Among several variables measuring perceptions of governance, the most suitable one for this study is government effectiveness. Government effectiveness is a measure of governance area which represents the capacity of government to effectively formulate and implement sound policies (Kaufmann et al., 2010).

The focus of government effectiveness is on "inputs" required for the government to be able to make and implement good policies and deliver public goods.[4]

The latter is measured by government final expenditure from World Bank. Many conventional studies have regarded fiscal capacity as an extractive capability of the state. Thus, the measurement of fiscal capacity has depended on the tax revenue of the state. However, the policy of promoting renewable energy is not the most urgent and important mission for the government in many cases. Since there exists an only limited amount of tax revenue, government make and implement policies with considerations of their priorities. Based on this reason, I measure the fiscal capacity in RE policy areas with the share of government expenditure in GDP. As the share of general government expenditure in GDP represents a kind of financial burden given to the government, this study uses this indicator as a converse measurement for fiscal capacity in renewable energy policy.

② Instrument constituency

The gross domestic product (GDP) per capita has been widely used to measure the relative level of income. This study use GDP per capita as a proxy representing society's interests in RE support policy instruments. Also, the amount of CO_2 emission is another proxy representing society's interests in RE support policy instruments. Since renewable energy generation can substitute the role of conventional fossil fuel generation in energy supply system, it also contributes to the decrease in the pollution and the transition to the sustainable development.

However, the preference of interest groups such as conventional energy generators may have a negative influence on the policy instruments that support RE generation. To measure the

[4] The government effectiveness indicator of WGI is comprised of survey responses on the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (Kaufmann et al., 2010).

impacts from competing interest groups, I use the shares of electricity production from fossil resources and nuclear resources in total national energy production.

Also, as a control variable, data on energy imports was gathered from UN statistics, to rule out the impact of differences in energy dependence**.** Specific measures and data sources are listed in Table 6.

<Table 6>. Dependent and independent variable explanations and data sources

Variable		Source	Unit
Dependent Variables	Adoption Rate of Regulatory Policy instruments	REN21	% of total regulatory instruments
	Adoption Rate of Incentives and Fiscal Policy instruments	REN21	% of total incentive instruments
Policy capacity	Government effectiveness	World Bank (Governance Indicators)	-2.5~+2.5
	General government final consumption expenditure	World Bank (World Development Indicators)	% of GDP
Instrument constituency	GDP per capita	UN Statistics	log transformed
	CO_2 emission	Carbon Dioxide Information Analysis Center	kg, log transformed
	Electricity production from nuclear resources	WRI (CAIT)	%
	Electricity production from fossil resources	WRI (CAIT)	%
Control variable	Energy imports	UN Statistics	% of energy use

3.3. Longitudinal analysis

Investigating the influence of government capacity and instrument constituencies on RE instrument mixes is challenging. Since the country-year structure of data can result overlapping spatial and temporal effects on the model. This study confirms the presence of heteroskedasticity, panel auto-correlation, and contemporaneous correlations by running a few tests (Likelihood ratio test, Wooldridge test, Pesaran's test).

To solve these problems by mitigating errors in the data structure, replacing standard errors of OLS with corrected standard errors which consider panel attributes is a suitable solution to reduce the damage of efficiency and to improve the accuracy (Beck and Katz, 1995). Therefore

this study employ panel corrected standard error (PCSE) estimator models suggested by Beck and Katz (1995).

4. Results and discussion

The descriptive statistics analysis and panel analysis is conducted on the theoretical base to allow differentiated recommendation for each policy tools. See Appendix 3 for the descriptive statistics. Table 7 displays the results of panel data analysis using PCSE estimators.

<Table 7>. Panel data analysis(PCSE) results

Variables	**Regulatory Instrument Model (DV: Regulatory Instrument Mix)**		**Economic Instrument Model (DV: Economic Incentive Instrument Mix)**	
	Coefficient	Standard Errors	Coefficient	Standard Errors
Government Effectiveness	**5.162***	2.836	1.947	4.425
Government Expenditure	0.840	0.808	-0.057	1.191
Electricity from Nuclear Energy Generation	-0.075	0.055	-0.106	0.081
Electricity from Fossil fuel Generation	0.041	0.062	**-0.091***	0.053
GDP per capita (log transformed)	4.072	2.608	**5.990***	3.451
Energy Imports	**0.026*****	0.007	**0.034*****	0.009
CO_2 Emissions (log transformed)	**1.805***	0.923	**5.701*****	1.701
Constant	-28.001	23.001	-37.114	32.898
	R^2=0.3506, Wald $chi^2(7)$=231.3		R^2=0.3205, Wald $chi^2(7)$=29.29	

Notes: panel corrected standard errors are reported ***, **, * denote significance at 1%, 5% and 10% significance levels, respectively.

4.1. Panel analysis of regulatory instrument model

Starting with the model of regulatory instruments adoption, there is a significant and positive effect of policy capacity (government effectiveness) on instruments adoption. This result supports my first hypothesis, which argues that the likelihood of policy adoption increases with policy capacity. However, government's final expenditure, which captures the fiscal capacity of countries, has no significant effect on the adoption of regulatory instruments.

Among variables representing the influence from instrument constituency, only a higher amount of CO_2 emission has a significant positive effect on the adoption of regulatory instruments. With respect to the hypothesis, the interests in sustainable development do have implications for the adoption of policy supporting RE. As for the control variable, the higher share of energy imports compared with energy use in the country also shows a significant and positive effect on the adoption of regulatory instruments.

4.2. Panel analysis of economic instrument model

The results of economic instruments model also support the third hypothesis, which argues that the likelihood of policy instruments adoption increases with a society's income levels. Moreover, the amount of CO_2 emission has a positive and significant influence on the adoption of economic incentive instruments.

A higher share of energy production from fossil fuels has a significant negative effect on the adoption of incentive instruments. On the other hand, a share of nuclear power generation in the national energy supply system, which captures the influence from interest group supporting nuclear energy, has no significant effect. Thus, the finding for the conventional energy interest groups is only partially consistent with the hypothesis, and also the results of previous research analyses. As can be observed in the model of the regulatory instrument, the share of energy

import compared with energy use has also a significant and positive relationship with the adoption of incentive instruments.

4.3. Discussion

First, our results highlight the positive influence of policy capacity (government effectiveness) to the adoption of regulatory instruments. Thus, it is supported that the differences between policy instruments can be related to the various capacity requirements.

On the other hand, I do not find statistically significant results for the fiscal capacity (government final expenditure). This might be due to the research model of this study since the measurement might be inadequate to capture the government's fiscal capacity in RE policy areas. Therefore, more detailed information about fiscal capacity in renewable energy policy area is needed for better measurement. In addition, the increasing demand for promoting renewable energy may influence on the potential change of usual assumption between policy instruments and fiscal burden of government. In the case of South Korea, the government had abolished FIT on account of a heavy budgetary burden. However, the subnational government in Korea such as Seoul has adopted FIT to response the increasing demands from small scale RE generators and a civil society who wish to promote renewable energy.

Second, our results show that preferences of society as proponents of policy supporting RE have partial impacts on the adoption of policy instruments. An income level of the society (GDP per capita) has an estimated significant effect on the adoption of economic incentives but not for regulatory instruments. Although the type of policy instrument used as a dependent variable is different, previous study (Jenner et al., 2012) have provided a valid interpretation for this result that prosperous country has enough resources to support renewable energy. Moreover, the results from both instrument models confirm the hypothesis that a society's interests about climate change can be positively correlated with RE instruments adoption. This may be quite

positive sign for RE development because having a high CO_2 emission is probably associated with the high percentage of fossil fuel based energy production in current status. Despite high opportunity costs of moving towards more renewables, countries feel a greater need to reduce GHG emission from fossil fuel generation to meet climate policy targets.

Third, we provide only partial evidence for hypotheses about interest groups in conventional energy industries. The influence of fossil fuel has no significant and positive relationship with the adoption of regulatory instruments. Otherwise, there exist a significant and negative influence on the adoption of incentive instruments. This would be the evidence for the clear distinction between an instrument constituency's attitudes toward different instruments. For example, conventional power generators may have different opportunity costs and interests in each of RE policy instruments. For example, although their first best solution is no regulation, they would prefer the regulatory instruments to the incentive instruments (Jenner et al., 2012)

The lack of significant impact from the power of nuclear energy on the adoption of RE policy instruments is noteworthy. Although some of the previous studies have assumed that nuclear energy is in competitive relation with renewable energy as substitutes for fossil fuel energy, their relationship can be changed in practice. Certainly, there exist contrasting perspectives and attitudes toward nuclear energy among countries in recent years. In some countries such as South Korea and France, nuclear energy has been regarded as a green technology for sustainable development. However, Germany already declared phased out of the nuclear power plants and replace them with renewable energy generation. Due to these different attitudes among the countries, the status of nuclear energy varies around the world.

5. Conclusions and policy implications

While the number of countries using multiple RE policy tools continue to rise, investigating the dynamics of policy adoption still has some difficulties. Following the claim of Yi and Feiock

(2012), this might be due to the lack of progression in theoretical and empirical research models. From this aspect, the objective of this study is searching for the possible research model to investigate the dynamics of RE policy adoption.

Based on the theoretical approaches from previous studies, I examined the potential influence of government capacity and instrument constituency on the adoption of RE policy instruments. For empirical analysis, measurement for policy mixes is comprised of several stages. Specifying different policy tools enables the more detailed modeling of government capacity and instrument constituency. And measuring policy mix with the adoption percentage of substantive instrument captures the various degrees of the policy mix.

The most important contribution of this study would be the selection of cases. While most of previous studies have been included advanced countries such as the United States and EU, I select the data from many developing or underdeveloped countries. For the success of international efforts to the sustainable development, the role of developing countries is a crucial key (Stadelmann and Castro, 2014: 420). Concretely, the results of this study shed light on the theoretically expected determinants of the adoption of RE policy instruments for developing countries and underdeveloped countries. To achieve their policy goals, governments should enhance not just an effectiveness in policy process but also the fiscal capacity to secure the budget required for specific policy instruments. Moreover, the preferences of civil society also play a significant role in the policy adoption process. For these reasons, to derive overall consensus among citizens about the necessity of adopting RE policy could be an urgent priority for the governments.

Despite the modeling and empirical analysis of the dynamics of RE policy instrument adoption in this study, this research has some limitations. First, the data used to construct the dependent variables are limited to the widely used instruments. Since gathering time-series data needs continuity of information, I omit some of the instruments in regulations and economic

incentives. Second, the distinction between policy tools is a simplistic approach. This is because the categorization of policy instruments is needed to perform a comparative study of 55 countries. In addition, for further and detailed analysis of policy mix, more qualitative work on the interplay between policy instruments is required.

Appendix

A.1. Summary of selected previous studies

<Table A1> Summary of selected previous studies

Vachon & Menz (2006)	Jenner et al. (2012)	Schaffer & Bernauer (2014)
DV: Adoption of four specific green electricity policies (RPS, Net metering rules, Public benefit funds, Generation disclosure rules)	**DV**: Adoption of regulation (FIT, RPS)	**DV:** Adoption of any of the two types of policy instruments of interest (Fit, GCS)
Economic interests Renewable potential, Coal production, Electricity from fossil fuels	**Private interest theory** Years of existence of a state chapter of the International Solar Energy Association, Market power of utilities on state electricity markets, Years of existence of a national nuclear association	**Economic conditions** GDP per capita, GDP
		Energy supply system CO_2 emissions, Electricity production from oil, gas and coal sources, CO_2 intensity
Political interests Computation of senate votihg history and house voting history	**Public interest theory** GDP, Electricity price per kwh for private consumers, Energy intensity, State unemployment rate, National air pollution	**Political system characteristics** Federalism, Proportional representation, Left orientation of chief executive, Right orientation of chief executive, Center orientation of chief executive, Left orientation of cabinet, Right orientation of cabinet, Center orientation of cabinet
Social interests Computation of median income, college degree and membership in environmental pressure groups	Ratio of neighbor states that have already implemented RES-E support schemes and the total number of neighbor states, Parliamentary seats that are occupied by the national Green party, State's electoral family, EU Directive 2001/77/EC on RES-E, Solar energy Potential	**International factors**

A.2. Case selection

The name of countries for the sample is listed below.

Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Sri Lanka, Chile, Costa Rica, Cyprus, Czech Republic, Denmark, Dominican Republic, El Salvador, Estonia, France, Germany, Greece, Guatemala, Hungary, India, Ireland, Israel, Italy, Jordan, South Korea, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Netherlands, New Zealand, Nicaragua, Norway,

Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russia, Slovakia, South Africa, Spain, Sweden, Switzerland, Thailand, Tunisia, Ukraine, Egypt, United Kingdom, United States (Total 55 countries)

A.3. Descriptive statistics

<Table A2> Descriptive statistics

Variables	Obs	Mean	Std Dev.	Min	Max
Adoption rate of Regulatory Instruments	495	30.05	24.52	0	100
Adoption rate of Economic Incentive instruments	495	41.19	29.51	0	100
Government Effectiveness	495	0.77	0.89	-0.96	2.36
Government Expenditure	495	5.59	0.91	0.69	6.44
Electricity from Nuclear Energy Generation	495	9.55	1.19	6.83	11.61
Electricity from Fossil fuels Generation	495	4.34	1.63	0.90	8.67
GDP per capita (log transformed)	495	59.00	29.74	0.39	100
Energy Imports	495	12.38	19.12	0	80.54
CO_2 Emissions (log transformed)	495	23.01	102.73	-764.3	99.95

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