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博士論文審査結果報告
Report on Ph.D. / Doctoral Dissertation Defense

National Graduate Institute for Policy Studies (GRIPS)
政策研究大学院大学
Professor TANAKA Makoto
教授　田中　誠

審査委員会を代表し、以下のとおり博士論文審査に合格したことを報告します。

On behalf of the Doctoral Dissertation Review Committee, I would like to report the pass result of the Doctoral Dissertation Defense as follows.

プログラム名 Program	科学技術イノベーション政策プログラム Science, Technology and Innovation Policy Program	
学位申請者氏名（ID） Ph.D. Candidate (ID)	伊藤　和哉 (DOC18151) ITO Kazuya	
Dissertation Title 論文タイトル (タイトル和訳)	Renewable Energy Policy and Investment Decision-Making in Electricity Markets 再生可能エネルギー政策と電力市場における投資の意思決定	
学位名 Degree Title	博士（公共政策分析） Ph.D. in Public Policy	
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論文最終版提出日/ Submission Date of the Final Dissertation	2022 年 2 月 22 日/ February 22, 2022	
審査委員会/ Doctoral Dissertation Review Committee	主査 Main referee	田中　誠 TANAKA Makoto
	審査委員 Referee	根井　寿規 NEI Hisanori
	審査委員 Referee	飯塚　倫子 IIZUKA Michiko
	審査委員 Referee	髙嶋 隆太 東京理科大学 TAKASHIMA Ryuta Tokyo University of Science
	審査委員（博士課程委員会） Referee (Doctoral Programs Committee)	土谷 隆 TSUCHIYA Takashi

※ タイトルが英文の場合、文部科学省に報告するため、和訳を付してください

Please add a Japanese title that will be reported to MEXT.

1. Summary of Defense and Evaluation

The aim of this dissertation is to investigate the impact of renewable energy policy and regulation on investment decision-making in renewable energy sources and associated network infrastructure. In Chapter 2, the candidate develops a game theoretic real options model for the investment decision-making of power generation companies (GENCO) and the transmission system operator (TSO) under uncertainty. He considers several scenarios to examine the effects of the subsidy scheme called feed-in premium (FIP) and the investment cost reduction of wind power generation. He demonstrates different impact of FIP and the investment cost reduction on investment timing and capacity expansion of infrastructures. In Chapter 3, he investigates the investment decision-making of prosumers, based on complementarity modeling of an electricity market. He analyzes prosumers' investment decisions in solar photovoltaic (PV) panels under different pricing schemes, namely net metering and net billing. The study finds that social surplus under net billing is larger than that under net metering.

Studies that combine both the real options approach and game theory in the context of generation and transmission investment have been scarce in the literature. Pricing schemes for distributed energy resources have recently received attention but the issues have not been fully investigated in the literature. Chapters 2 and 3 contribute to the literature by developing an analytical framework based on novel game theoretic real options and comprehensive complementarity modeling approaches.

The referees were generally satisfied with the contribution of the dissertation. They however suggested several areas for improvement, particularly better exposition of the dissertation. After several revisions to the dissertation, the main referee was satisfied that the revisions were made appropriately in line with the suggestions by the referees. The doctoral dissertation review committee recommends that GRIPS award the degree of Ph.D. in Public Policy to Mr. Kazuya Ito.

2. Dissertation overview and summary of the presentation.

Concerns about climate change have spurred policymakers to implement measures to promote further renewable energy sources such as wind and solar energy. Renewable energy policy and regulation affect the long-term decision-making of the participants in the restructured electricity market. The aim of this dissertation is to investigate the impact of such policy and regulation on investment decision-making in renewable energy sources and associated network infrastructure. This study develops an analytical framework based on two different methodologies, i.e., the real options approach and complementarity modeling.

In Chapter 2, the candidate develops a game theoretic real options model for the investment decision-making of power generation companies (GENCO) and the transmission system operator (TSO) under uncertainty. The model is framed as a game for investment in generation and network infrastructures, in which GENCO determines the capacity and TSO decides the investment timing. Particularly, the focus of this study is on the case where a region with abundant wind energy resources is connected by a transmission line to remote demand centers. He considers several scenarios to examine the effects of the subsidy scheme called feed-in premium (FIP) and the investment cost reduction of wind power generation. He demonstrates different impact of FIP and the investment cost reduction on investment timing and capacity expansion of infrastructures. FIP delays investment timing, while encouraging investment in a larger capacity. On the contrary, the investment cost reduction speeds up investment timing, while encouraging investment in a relatively smaller capacity. Moreover, he shows that if the investment cost of wind power generation falls sufficiently because of further technological innovation, social surplus can increase significantly even without the subsidy scheme, which would mitigate the financial burden of implementing FIP.

In Chapter 3, the candidate investigates the investment decision-making of prosumers that are both producers and consumers with distributed energy resources, based on complementarity modeling of an electricity market with a three-node network. He analyzes prosumers' investment decisions in solar photovoltaic (PV) panels under different pricing schemes, namely net metering and net billing, which allow prosumers to receive compensation in different manners for their electricity sales to the market. In net metering, prosumers' electricity consumption and sales are priced at the same rate, while net billing generally sets the sale price of electricity lower than that for consumption. The study finds that net metering leads to a greater PV capacity but a higher transmission tariff compared to the case of net billing. Overall, social surplus (i.e., surplus for prosumers, conventional consumers, conventional producers, and the system operator) under net billing is larger than that under net metering. He also extends the model to incorporate operation of battery energy storage systems, which allow prosumers to store excess electricity during the peak period. The results are consistent and robust with and without battery storage operation.

Studies that combine both the real options approach and game theory in the context of generation and transmission investment have been scarce in the literature. Chapter 2 proposes a novel game theoretic real options model for the decision-making of capacity expansion and investment timing of GENCO and TSO in the context of renewable energy penetration, and evaluates the subsidy scheme of FIP.

Pricing schemes for distributed energy resources have recently received attention but the issues have not been fully investigated in the literature. Chapter 3 contributes to the literature by proposing a comprehensive complementarity modeling approach for prosumers' investment decisions in PVs under the commonly implemented schemes of net metering and net billing.

The candidate presented the dissertation over Zoom. He then responded to the questions and comments from the referees.

3. Evaluation Notes from the Doctoral Dissertation Review Committee (including changes required to the dissertation by the referees)

The referees were generally satisfied with the contribution of the dissertation. They however suggested several areas for improvement, particularly better exposition of the dissertation. The comments from the referees include:

- Change the title of the dissertation to better reflect the content.
- Create a list of acronyms.
- Provide a chart that illustrates the structure of the dissertation and a figure that illustrates the case study in Chapter 3.
- Better explain some terminologies such as net metering/net billing and ISO/TSO.
- Better explain the model setup such as the assumption for GENCO and LNG.
- Describe the differences in renewable energy technologies in the models.
- Describe the relationship between the case studies and the real-world markets/networks.
- Elaborate on the mechanism about how the uncertainty affects the results for social surplus in Chapter 2.
- Elaborate on the mechanism about how the PV capacity sharply rises in a certain range of the PV capital costs in Chapter 3.
- Discuss how investment in R&D should be made with respect to renewable energy technologies to increase social surplus.

Under the rules of the defense, the confirmation of satisfaction was delegated to the main referee. About two weeks after the defense, the candidate sent the revised dissertation to the main referee along with a note that described changes in response to the suggestions of the referees. After several further revisions to the dissertation, the main referee was satisfied that the revisions were made appropriately in line with the suggestions by the referees.

4. Confirmation by the Main Referee that changes have been done to the satisfaction of the referees and final recommendations

After a plagiarism check, the main referee confirmed that the revisions were satisfactory and the quality of the dissertation was improved. On February 22, 2022, the final version of the dissertation was submitted to GRIPS.

The doctoral dissertation review committee recommends that GRIPS award the degree of Ph.D. in Public Policy to Mr. Kazuya Ito.