PURE OR HYBRID?: POLICY OPTIONS FOR RENEWABLE ENERGY

Ryuta Takashima, Tokyo University of Science, Phone +81 4 7122 1372, E-mail: takashima@rs.tus.ac.jp
Yuta Kamobayashi, Tokyo University of Science, E-mail: 7414609@ rs.tus.ac.jp
Makoto Tanaka, National Graduate Institute for Policy Studies, E-mail: mtanaka@grips.ac.jp
Yihsu Chen, University of California Santa Cruz, E-mail: yihsuchen@ucsc.edu

Overview

Recently policymakers have implemented various policies for reducing greenhouse gas emissions owing to~~by~~ concerns of~~about global warming and~~ climate change. Those ~~e~~ policies include schemes for ~~supporting and~~ promoting renewable energy such as feed-in tariff (Fi~~I~~T), feed-in premium, Fi~~I~~T-contract for difference, and renewable portfolio standards (RPS). Those policies directly impact the power prices by favoring power produced by renewables~~Scince these polies affect the price in the power market due to polisies or regurations for generation outputs, the policymakers have revised regulatory prices and targets according to introduction outputs for renewable energy~~. A number of articles have studied the impacts of various ~~addressed the problem of relationship between~~ renewable energy policies~~y~~ on ~~and~~ the ~~e market equilibrium~~ energy market outcomes (Fischer, 2010; Tanaka and Chen, 2013; Hibiki and Kurakawa, 2013; Siddiqui et al., 2016). Especially, Hibiki and Kurakawa (2013) compare the RPS to the Fi~~I~~T schemes from the aspect of the social welfare. They find that when the marginal damage cost is relatively high, the social welfare for RPS is higher than that for Fi~~I~~T ~~under conditions where~~when the renewable energy generator is a price taker. However, as many countries, as alluded to in ~~As shown in~~ REN21 (2016), have ~~more~~ implemented a combination of multiple policies, there is a need to understand their market impacts and compare to either RPS or Fit alone. This study specifically examines the efficiency of the "hybrid" policy scheme consisting of RPS and FiT. ~~than one policy, that is, a hybrid policy is implemented in many countries or regions. In this work, we investigate an effect of a hybrid policy of RPS and FIT on the market equilibrium compared to pure policy as RPS and FIT.~~

The Model

We consider~~In this work, as shown in Fig. 1 we consider~~ two types of power generators in the electricity industry: ~~as~~ non-renewable energy (NRE) and renewable energy (RE) generators (Fig. 1)~~.~~. These two types of producers are jointly subject to ~~. We assume that there are both players of NRE and RE generators in the power market for the~~a RPS requirement while only the RE producer is supported by the ~~scheme, i.e., the both generators can influence the power price. On the other hand the market player is just NRE generator for the~~ Fi~~I~~T scheme. That is ~~, i.e.,~~the RE generator's profit is indirectly impacted~~eds~~ by~~on~~ the power price through~~via~~ the FiT scheme. ~~It is assumed that~~The total generating cost for each generator is assumed to be ~~qa~~ quadratic function, with the ~~and that the~~ rate of increase in marginal cost (or the slope of the marginal cost) for RE is larger than that for NRE. The power prices in the market is given by a~~n~~ linear~~the~~ inverse demand function for total output. The damage from ~~cost of~~ greenhouse gas emissions is assumed to be a convex quadratic function of ~~in only the generation output from the~~ NRE's output. Similar to ~~Therefore we also assume that the function is an quadratic one of output. Likewise~~ Siddiqui et al. (2016), we model the interaction between an electricity industry and the government ~~a policymaker~~ by assuming that a ~~the~~ policymaker~~'s objective is to~~ maximizes the social welfare, accounting for the ~~composed of a~~ social surplus in consuming and producing power minus~~the power market, and the~~ damage caused by cost from the greenhouse gas emissions. We consider the following scenarios~~In order to explore the effect of the hybrid policy of RPS and FIT, we allow for the following scheme settings~~:

Central planning (CP): As a bench-mark case, this setting has a central planner who simultaneously decides outputs for all power generations by maximiz~~s~~ing the social welfare.

RPS: At lower level, NRE and RE generators choose the outputs subject to the ~~for arbitrary~~ RPS target determined by ~~the~~ the government at the upper level by ~~by~~ ma~~i~~ximizing social welfare.~~ng their profits. On the other hand, the policymaker decides the RPS target maximizing the social welfare at upper level.~~

FIT: Similar to the RPS case, but with only the ~~The player in power market is just N~~RE generator is supported by the Fit that is optimally determined by the government ~~governemtn~~ at the upper level.~~who can influence the power price. RE generator chooses the output for arbitrary FIT price by maximizing the profit. At upper level, the policymaker sets the FIT price maximizing social welfare.~~

Hybrid policy (HP): NRE and RE generators decide their outputs subject to~~in~~ a combination of ~~the hybrid policy of~~ RPS and Fi~~I~~T with both the RPS target and the FiT determined by the government.~~. At upper level, the policymaker decides both of the RPS target and the FIT price maximizing social welfare.~~

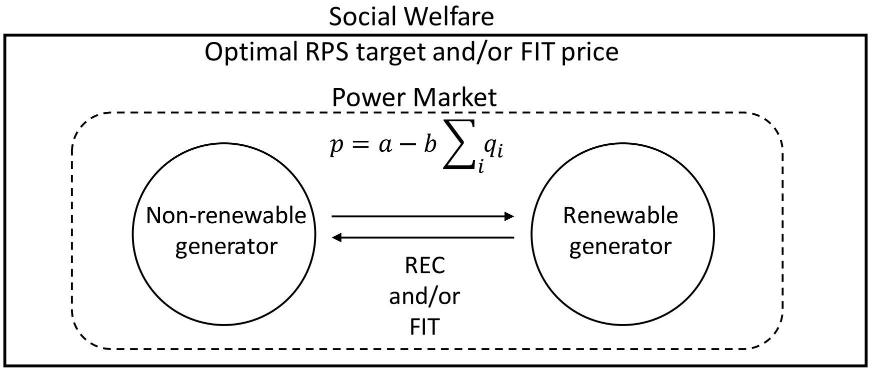

Figure 1. Model for pure or hybrid policy

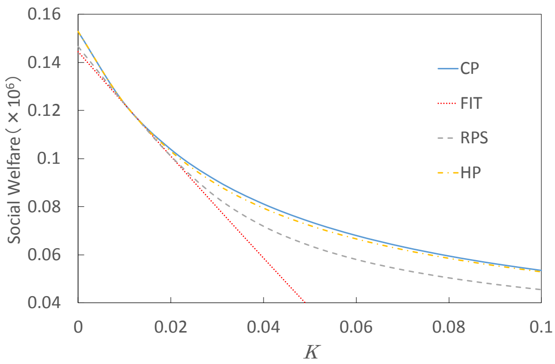

Figure 2. Social welfare for each scheme

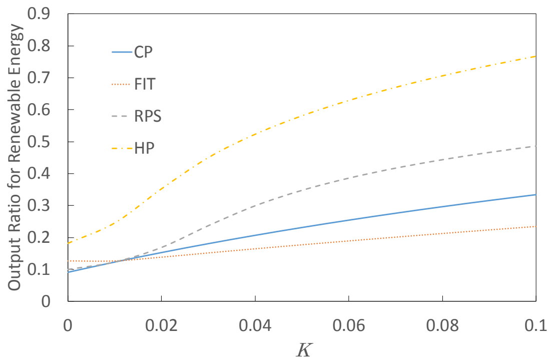

Figure 3. Output ratio for renewable energy for each scheme

Results and Discussions

We follow the assumption by Tanaka and Chen (2013) and Siddiqui et al. (2016) for the ~~In this analysis, we use same~~ parameter values. Figs 2-3 report the main outcomes. ~~as previous papres, Tanaka and Chen (2013) and Siddiqui et al. (2016).~~ Fig. 2 plots the resulting social welfare a~~s~~gainst the marginal damage K for four scenarios~~shows an effect of the rate of increase in marginal cost of emissions, K on the social welfare for each scheme~~. Fig. 2 indicates that the ~~The~~ maximiz~~s~~ed social welfare for the HP (hybrid~~ed~~ policy) is greater than those for pure polic~~s~~ies as RPS and Fi~~I~~T, suggesting ~~. This means that~~ the flexibility of HP due to choices of RPS and FiT ~~has a flexible value that the policymaker can choose the fraction for policies for FIT and RPS~~effectively enhances social welfare. This is contrast to ~~Unlike~~ Hibiki and Kurakawa (2013), concluding that the Fi~~I~~T scheme always results in the~~he~~ lowest maximiz~~s~~ed social welfare for any given K. The impact of K to the output ratio for renewable energy is illustrated in Fig. 3. This figure implies that ~~As can be seen from this figure,~~ the Fi~~I~~T results in the lowest ratio for renewable generation. This is mainly because NRE generator needs to increase outputs by~~due to~~ purchasing the electricity from RE generator due to ~~through~~ Fi~~I~~T scheme, leading to the ~~. Therefore the power price is smallest one~~lower price under the Fi~~I~~T case~~setting~~. The analysis also suggests that the ~~It turns out that the~~ optimal RPS requirement under the HP is greater than that of~~for~~ RPS. Since the Fi~~I~~T price comes ~~becomes the~~closer to the power ~~electricity~~ price ~~for~~ when K becomes relatively large. This implies that ~~value of K, and thereby~~ the market power for the NRE producer can be effectively mitigated under the HP~~generator might be mitigated~~ case, leading to the power price compat~~t~~ible with the PC case~~the HP setting may be close to perfect competition~~.

Concluding Remarks

T~~In t~~his work explores the efficiency of the hybrid policies, i.e., RPS and FiT, by com~~a~~paring it to the single policy scheme (either ~~the~~ RPS or ~~, and~~ FiT) ~~cases~~. ~~we examine the market competition of NRE and RE generators in RPS, FIT, and their hybrid schemes. The effect of emission cost on the social welfare and the output ratio for renewable energy is numerically analyzed.~~ We find that the maximized social welfare for the hybrid policy is greater than those for pure policies, e.g., ~~as~~ RPS ~~and~~ or Fi~~I~~T. Under the hybrid policy scheme, ~~In addision~~ the ratio of ~~output ratio of~~ renewable energy output to the nonrenewables ~~for hybrid policy~~ is rep~~r~~orted to be ~~also larger than those for pure~~greater than that under the ~~other~~ single ~~policie~~policys. Thus, the hybrid policy can effectively~~is most effective means of~~ promote~~ing~~ renewable energy. In the future work, we will extend the model to introduce uncertainty of the demand. We will also allow for investment decisions and capacity choice for renewable energy.

Acknowledgements

The authors would like to thank the participants for the Section on the ENRE in the 2015 INFORMS Annual Meeting for their helpful comments and suggestions. This work is partially supported by the Grant-in-Aids for Scientific Research (B) (grant No. 15H02975) from Japan Society for the Promotion of Science.

References

Fischer, C. (2010): "Renewable portfolio standards: When do they lower energy prices?" Energy Journal, 31, 101-120.

Hibiki, A. and Y. Kurakawa (2013): " Which is a Better Second Best Policy, the Feed-in Tariff Scheme or the Renewable Portfolio Standard Scheme?" RIETI Discussion Paper Series 13-J-070. (in Japanese)

Renewable Energy Policy Network for the 21st Century/REN21 (2016): "Renewables 2016 Global Status Report." REN21, Paris.

Siddiqui, A., M. Tanaka and Y. Chen (2016): "Are targets for renewable portfolio standards too low?: The impact of market structure on energy policy." European Journal of Operational Research, 250, 328-341.

Tanaka, M. and Y. Chen (2013): "Market power in renewable portfolio standards." Energy Economics, 39, 187-196.