STIMULATING RENEWABLE ENERGY AND POLICY DESIGN: A MODEL ANALYSIS OF THE POWER MARKET

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Overview

Within the EU the share of renewable energy will increase strongly in the near future which may have significant effects on how the electricity market functions as well as the costs for electricity users. The EU's Renewable Energy Directive (2009/28/EC) sets a binding target of 20 percent final energy consumption from renewable sources by 2020. To achieve this, EU countries have committed to reach their own national renewable targets ranging from 10 percent in Malta to 49 percent in Sweden. Under such an increase, the electricity market might need to be redesigned to avoid adverse economic or societal effects of the surge in renewable energy.

The increase in supply from renewable energy sources (RES) strongly affects electricity markets. The distance between production and consumption may create bottlenecks in the grid. National policies to stimulate RES result in higher costs for energy users and have consequences for energy users in other countries. The intermittency of RES makes power flows more volatile and less predictable. Moreover, the price-reducing effect of renewable energy reduces the incentives for investments in coal- and gas- fired plants, which are still needed for security of supply in case there is no wind or sunshine. Hence, the surge in RES may endanger the balance among efficiency, sustainability and reliability of the energy market.

Applying a designer's perspective, we analyse how alternative designs of the electricity market affect these objectives. By electricity market design, all institutional aspects are meant, including the regulation of networks, the way wholesale and retail markets are organized, the instruments used to foster renewable energy, and the integration of the energy system (gas, power and heat). In this paper, we focus on two policy issues related to the increase in the share of RES.

The first policy option considered is related to the financing of subsidies which are needed to make investments in renewable energy profitable. Governments have a number of options, at least in theory, for collecting financial revenues to finance these subsidies. In several countries, end-users have to pay a levy on their energy bill, while in others subsidies are financed from charging fossil-fuel producers. In this paper we compare two alternative options: charging end-users of electricity or charging the producers of fossil-fuel electricity. For both options, we assess the consequences for the wholesale market, looking at efficiency, stability of prices and reduction in CO_2 emissions.

The second design option we consider is dynamic network tariffs. The newly adopted Energy Efficiency Directive (2012/27/EU) requires the removal of network tariffs that would impede energy efficiency and/or demand response. Adopting dynamic network tariffs facilitates consumers to respond to electricity prices. A higher shadow price signals the tension of the network utilization and the need for network extension. By linking network tariffs to the real-timing network tensions, the electricity consumption might shift more efficiently from peak to off-peak hours. In this paper we analyze the spillover effects of dynamic networks tariffs on the wholesale market looking, again, at efficiency, stability of prices and reduction in CO_2 emissions.

Methods

We first build a theoretical model where power producers invest strategically in generation capacity in the long-term and compete in electricity output in the short-term. Closed-form solutions for market equilibrium regarding electricity output and prices are derived. Given the RES support levels, the optimal investment decisions regarding fossil-fuel fired plants and RES capacity can be obtained. Then, we calibrate the model parameters using the Dutch electricity market data in 2014. Finally, the corresponding policy analysis for the Dutch electricity market is conducted based on the calibrated model.

In the long-term, power producers strategically decide the capacity investment both for fossil-fuel fired capacity and RES capacity. Note that we take the fact that there are subsidies for RES investment into account. In general, the subsidy levels for off-shore wind parks and solar cells are different. In the short-term, the power market is modelled as imperfect competition. In most European countries, there is a high concentration rate of power producers, see e.g., Willems et al. (2009), Mulder et al. (2015), ten Cate and Lijesen (2004). Hence, it is reasonable to model the electricity market as a few centralized power producers who can exercise market power with a number of fringe suppliers who are price-takers. In addition, we view the market structure roughly the same from the current situation to the year 2020.

Results

RES support levels regarding off-shore wind parks and solar cells have effects on the investment decision for centralized and decentralized power producers. Subsidies in favour of off-shore wind parks increase the RES generation capacity by centralized power producers. The investment incentives for fossil-fuel generation capacity come from the stochastic nature of RES. In case of low production of RES, there will be scarcity prices hence the investment regarding fossil fuels will be rewarded by a higher electricity price. Subsidies for solar cells increase capacity of fringer suppliers, hence the market power exercised by centralized power producers is further limited and the market price tends to be more competitive.

We find that imposing a tax on conventional power production appears to harm consumers more than a tax on consumption. In case of producer taxes, consumers face a relatively strong decrease in consumer surplus. Although producers of renewable energy realize a higher surplus because of the increase in wholesale prices, one may expect that such an increase will result in a redesign of the subsidy scheme in order to transfer these windfall profits to society. A tax on fossil-fuel production has a stronger impact on domestic emissions of CO_2 than a tax on consumption of electricity, this effect may be largely neutralized through the increase in foreign production resulting from the increase in import.

We explored two options for dynamic tariffs: a simple peak/off-peak system and a system with hourly fluctuating prices related to the level of the hourly load. We also find that consumers suffer more from a hourly tariff scheme than from a peak/off-peak system. In the former case, the wholesale price is significantly larger, resulting in lower consumer surplus. Also for producers, a peak/off-peak system seems to be more attractive than a system with hourly varying network tariffs. The difference in producer surplus between these two policy options, however, is not large.

Conclusions

The ambition to transform electricity markets from a fossil-fuel based industry to an industry based on renewable energy, creates a number of challenges. In this paper we address two of them by using a partial equilibrium model of the power market which is calibrated on the characteristics of the Dutch market. The model includes both short-term and long-term (investment) decisions by power producers and takes the stochastic nature of renewable energy supply in account, just as trade relations with the neighbouring market. We find that imposing a tax on fossil-fuel electricity production harms electricity consumers more than a tax on electricity consumption. We also find that hourly varying network tariffs which are related to the overall level of load have a stronger negative effect on consumer surplus than a simple peak/off-peak system.

Although this analysis is based on a concise model calibrated on the 2014 characteristics of the Dutch power market, its value added is that it enables us to systematically analyze the consequences of alternative policy options. It is clear that the results of such a model exercise do not produce the final answers to policy debates, but they can serve as valuable inputs. In order to improve this value of the model it needs to be extended in a number of aspects. As the international dimension of energy markets and energy policy is increasingly a crucial element to take into account, the import and export should be modelled explicitly by including a number of foreign markets in the model. Such an extension should also include cross-border transport capacity as the international spill-overs in electricity market are constrained and affected by the limitations of this capacity. In order to be able to analyze the linkages between different type of environmental policies, the model should also be extended with a scheme for emissions trading as it is currently in place in Europe. Finally, to contribute to the debate on the ability of energy-only markets on foster sufficient investments, the model needs to be extended by one or more kinds of capacity mechanisms.

References

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