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The development of renewable energies and supply security: A trade-off analysis

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HIGHLIGHTS

- The effects of the transformation on the German electricity sector are analyzed.
- The paper focuses on the trade-off between green energies and supply security.
- The benefits of maintaining supply quality are compared with the investment costs.
- The costs of maintaining supply quality by far exceed the induced welfare gains.
- A strong focus on renewable energies endangers different energy-political goals.

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ABSTRACT

This paper analyzes the effects of the green transformation on the German electricity sector with respect to the energy-political triangle. It focuses on how the development of renewable energies will affect security of electricity supply. In a cost–benefit analysis, the value of supply security is compared with its costs of provision. More specifically, the benefits of maintaining the present quality of electricity supply are the avoided social damages from electricity outages and are compared with the respective investment costs in the low- and medium-voltage distribution grid. It is shown that the transformation process towards a green and decentralized production structure will be costly for society, even though the costs can be reduced by different measures.

1. Introduction

The impossibility of any longer ignoring the problem of greenhouse gas emissions has caused a shift in energy policy worldwide. For example, the governments of all Western countries have begun to emphasize the environmental aspects of their energy policy. However, designing an optimal energy policy should not be based on a one-dimensional view. Indeed, there are three benchmarks against which each energy-political initiative should be measured: its environmental soundness, its effects on security of supply, and its impact on energy prices. These three aspects comprise what may be called the energy-political triangle or, better yet, “trilemma,” a term that has the advantage of implying potential conflicts.

However, energy-political initiatives are usually studied one-dimensionally in terms of their explicit goal (see e.g., Telson, 1975), and the current situation of energy market transition in Germany is no exception. The importance of such approaches is not without value, of course, but with regard to the energy-political triangle, they are not sufficient. Therefore, using the German electricity market as an example, this paper analyzes environmentally motivated instruments with respect to their further consequences for the energy-political triangle.

Designing an electricity market always involves some tension between (normative or positive) economic considerations and technical requirements and possibilities. This is especially true in the matter of supply security. From an economic perspective, a fundamental problem is estimating the value of supply security since it is not reflected in any price (BET et al., 2011; De Nooij et al., 2007). The fact that security of supply is a public good complicates the situation: without a regulative intervention, it would be underprovisioned. As a consequence of these problems, security requirements for the net operators are mainly technically in nature (Woo and Pupp, 1992).

The economic literature, however, contains a wide range of papers that estimate the social value of supply security, which is often approximated by the (social) damages of outages (see e.g., De Nooij et al., 2007; Ghajar and Billinton, 2006; Willis and Garrod, 1996) and is the approach taken here. The different estimation methods are described later in a separate section.

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The obtained results imply both technical and economic considerations. For example, De Nooij et al. (2010) show how security standards based on estimating the value of supply security could replace those based on engineering practice. Thus, evaluating supply security can be seen as the first step in identifying socially optimal interruption levels (Baarsma and Hop, 2009). Furthermore, it can be used in case of shortages to optimally allocate electricity (De Nooij et al., 2007; Forte et al., 1995; Serra and Fierro, 1997). The present analysis combines technical and economic considerations such that the social welfare effects of the technically determined transition on the electricity market can be evaluated.

The analysis is based on the German electricity market, which in recent years has experienced a significant prioritization of environmental policy. The development of renewable energies is considered an appropriate way of reducing the country's CO_2-emissions. Therefore, renewable energy as well as several energy efficiency goals for 2020 were defined in a national energy concept initiating a transition process on the electricity market. Unless electricity imports shall increase, the planned nuclear phase-out has put even more pressure on this project. After the transformation, the structure of the electricity market will be decentralized instead of centralized as it is currently. The renewable energies instrument designed to accomplish this transition is analyzed in this paper with respect to its effects on the energy-political benchmarks. First and foremost, the social welfare effects with respect to the supply security targets are analyzed in a cost–benefit framework based on the contributions of De Nooij et al. (2010) and Tishler et al. (2006). Then, the paper goes one step further than, to the author's knowledge, most supply security analyses by comparing the value of supply security with its costs of provision. Based on that comparison, conclusions are drawn with respect to the climate targets and their effects on electricity prices.

The paper is organized as follows. Section 2 analyzes targets and measures of the transformation process in the German electricity market with respect to the year 2020 from the perspective of the energy-political triangle. The cost–benefit analysis follows in Section 3. After presenting the methodological approach in Section 3.1, the necessary cost and benefit parameters are calculated in Sections 3.2 and 3.3. Then, in Section 3.4, the resulting net present value is derived. Section 4 summarizes and discusses the results, draws conclusions, and discusses future research areas.

2. Targets and measures

The structure of the analyzed problem is illustrated in Fig. 1, where three policy levels can be distinguished: goals, indicators, and instruments. The energy-political triangle is the base of the analysis since it determines the goals, or targets, against which each policy instrument must be measured. But since these goals are stated in an abstract, sometimes even conflicting terminology, they are hardly testable. Thus, they are specified by three indicators, one for each goal, in the middle level. The indicators are precise and measurable parameters with which the effect of the instrument with regard to the specific goal can be tested. This interrelation between goals and indicators is illustrated by the dotted arrows in the figure. Finally, the upper level represents the policy instruments of interest in the present analysis; these are the development of renewable energies complemented by the second instrument, grid development. The solid arrows between the two upper levels point out the conceptual structure underlying the comparative-static approach, as will be explained in Section 3. The dashed arrows indicate other interrelations between the instruments and goals, respectively their indicators, that will be addressed in Section 4. The goals and indicators are next defined and explained in detail.

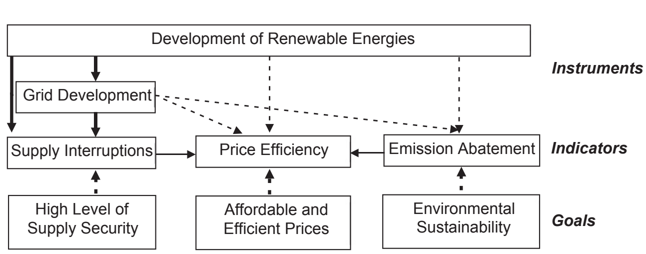

Fig. 1. Structure of the problem.

A primary target of energy policy is *environmental sustainability* of the electricity market. Environmentally unsound electricity production can have high social costs in form of external environmental damages. Problems of internalization arise from the public good character, especially in an international context, or because damages may occur with delay (and therefore may appear less likely). The most prominent example is the climate change induced by anthropogenic greenhouse gas emissions. Growing awareness of future climate problems has put the reduction of anthropogenic CO_2-emissions at the center of attention. The German government's central instrument for reaching the environmental goals is the development of renewable energies and thus is analyzed in this paper (see Fig. 1). Accordingly, the success in CO_2-emissions abatement is used as an indicator of the instrument's utility with respect to the climate goals (see the target indicator in Fig. 1).[1]

The second energy-political goal is a *high level of security of electricity supply*. In this paper, the term "security of electricity supply" is used in a purely technical sense: a low level of supply security is associated with a high number of supply interruptions and is therefore costly for society. A reliable grid-bounded electricity supply can be seen as an important economic good, meaning that provision of the grid, a natural monopoly, is of particular importance. Various indices measure the technical supply security level (for an overview, see CEER, 2008; VDE, 2006). In general, the most important dimensions of technical (supply) security are frequency, duration, and extent of supply interruptions.[2]

This paper focuses on supply security problems that arise from the net integration of decentralized renewable energies (see Fig. 2). The development of renewable energies leads to decentralized power production. To ensure a constant quality of structural supply security and to decrease the risk of network overload (i.e., the probability of a power outage), the grid must be appropriately designed, see CEER (2008) or VDE (2006). Consequently, grid development is a second energy-political instrument analyzed here (see Fig. 1). The suitable target indicator in this situation is the (cumulated) duration of supply interruptions (see Section 3.2.1). Moreover, the level of supply security in Germany is very high when looked at the international level (see Appendix A). Therefore, maintaining the status quo of supply security is often, and also in this paper, stated to be an energy-political minimum target.

Affordable and efficient electricity prices are the third dimension of the energy-political triangle. In industrialized countries, physical access to electricity is nearly universal. However, affordability

[1] The most important legislation is the German Renewable Energy Act (Erneuerbare–Energien–Gesetz, EEG) which came into law in 2000 and determines feed-in tariffs (Sections 16–22 EEG) for renewable energy electricity as well as feed-in priority (Section 5 EEG).

[2] For a more detailed overview of damages caused by supply interruptions, see BET et al. (2011), De Nooij et al. (2003), Frontier Economics (2008), and Wacker and Billinton (1989).