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Optimal renewable-energy promotion: Capacity subsidies vs. generation subsidies☆

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ABSTRACT

We derive optimal subsidization of renewable energies in electricity markets. The analysis takes into account that capacity investment must be chosen under uncertainty about demand conditions and capacity availability, and that capacity as well as electricity generation may be sources of externalities. The main result is that generation subsidies should correspond to externalities of electricity generation (e.g., greenhouse gas reductions), and investment subsidies should correspond to externalities of capacity (e.g., learning spillovers). If only capacity externalities exist, then electricity generation should not be subsidized at all. Our results suggest that some of the most popular promotion instruments cause welfare losses. We demonstrate such welfare losses with data from the German electricity market.

1. Introduction

Over the last two decades, many governments have introduced support schemes for electricity from renewable energy sources. According to the International Energy Agency's (IEA) *World Energy Outlook 2013*, $82 billion were used for these subsidies in 2012. In many countries, it is a declared political goal to further raise renewables' market share, so the total amount of subsidies will probably rise. In the "New Policies Scenario" projection, which assumes that the governments stick with their plans and serves as the baseline scenario, the IEA expects subsidies to reach almost $180 billion per year in 2035 (IEA, 2013).

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Without questioning whether this level of support is justified, the aim of this article is to derive optimal subsidy policies, so as to analyze whether currently popular promotion schemes are efficient. Our starting point is to recognize that justifications for promoting renewable energies can be divided into two categories: some justifications derive from capacity production and installation and others from electricity generation. Of the most prominent economic rationales, internalizing learning spillovers in manufacturing belongs to the former category, and second-best abatement of greenhouse gas emissions belongs to the latter.[2] Likewise, renewable-energy promotion instruments can be distinguished by whether they target capacity, through for example investment tax reductions, or electricity generation, through for example feed-in tariffs, quota systems or renewable portfolio standards. Despite its centrality to welfare analysis, the economic literature has almost completely neglected the difference between capacity and electricity generation when discussing optimal promotion schemes.

In this article, we analyze how the source of externalities should shape promotion and we demonstrate the implications of efficient policies for the supply behavior of renewable-energy capacity owners and for welfare. We derive optimal subsidies for electricity generation technologies, taking external benefits of capacity and of electricity generation into account, of which zero externalities of either capacity or generation are special cases.

Our model uses the framework of a competitive peak-load pricing model – that is, the decision variable is the supply quantity, but in situations of high demand, supply can be limited by capacity. We are not aware of any literature that explicitly analyzes optimal subsidies in such a framework.[3] The model's unique characteristic is the separation of capacity and electricity generation as targets of subsidies. To focus on the basic principles shaping optimal subsidies, we assume that there is only one moment in which electricity generation and consumption take place and that there is only one electricity generation technology. Additionally, we assume that the government has full information and it has access to non-distortive means of financing the subsidies (i.e., lump-sum taxes). While we think that neither of these assumptions changes the general insights of the model, we recognize that the full implications of these subsidies in a dynamic multi-technology market would have to be modeled explicitly.

We find that marginal subsidies for electricity generation should equal its marginal external benefits, and marginal subsidies for capacity should cover marginal external benefits of capacity. This rule allows derivation of a number of policy-relevant conclusions. For example, it implies that if there are only externalities of capacity (for instance, knowledge spillover effects of manufacturing photovoltaic modules), then electricity generation should not be subsidized at all. Furthermore, only under very specific circumstances do optimal promotion schemes for renewable energy resemble the demand-independent "fixed feed-in tariffs" that are popular in many countries.

While there is a large literature on renewable-energy promotion, as far as we know, only Bläsi and Requate (2010) and Reichenbach and Requate (2012) consider the implications of distinguishing between capacity and electricity generation. In these papers, learning spillover effects of capacity production are taken into account, making output subsidies for renewable-energy capacity producers optimal. However, in these models, electricity demand is deterministic and "capacity" is the number of firms, so that the distinction between capacity and electricity generation requires increasing marginal generation costs. By contrast, we model capacity as an explicit limit to electricity generation, which also allows to incorporate the case of constant marginal generation cost. In particular, this includes technologies like wind and solar power for which zero generation costs can be assumed. Moreover, our model takes into account that at the moment of investment, demand and capacity availability are uncertain.

Implicitly, Newbery (2012) also distinguishes the different sources of positive externalities by stating that capacity rather than electricity generation should be promoted for the case of wind energy. We analyze this point in a general way using a formal model.

The paper proceeds as follows. We describe the model setting in Section 2.1, derive a social planner's solution in Section 2.2, and a decentralized solution in Section 2.3. Section 2.4 defines the optimal subsidies. In Section 3, we use our framework to assess the welfare effects of the widespread policy instrument of fixed feed-in tariffs. A basic assessment of empirical welfare losses is provided in Section 4. Finally, Section 5 discusses the results.

[2] The learning-spillover argument states that productivity gains from learning how to produce renewable-energy capacity partly have a public-good character, so that too little renewables capacity, such as wind turbines, is built. The second-best abatement argument is based on the idea that, for whatever reasons, carbon prices cannot be set high enough to be optimal so that renewable energy sources should be subsidized to replace fossil-fuel electricity. See, for example, Rasmussen (2001), Jaffe et al. (2005), Bennear and Stavins (2007), Kverndokk and Rosendahl (2007), Fischer and Newell (2008), Helm and Schöttner (2008), Gerlagh et al. (2009), Kalkuhl et al. (2013). Other alleged reasons to promote renewable energies are fostering employment and increasing the security of energy supply. The employment objective can be interpreted as strategic trade policy (cf. Spencer and Brander, 2008), implying that manufacturing firms are subsidized to oust foreign competition. According to the energy security rationale (which includes reducing the dependence on foreign energy supply), the government should ensure that a high electricity generation capacity is not only produced but kept ready. Thus, both reasons hinge on capacity. For a comprehensive review of renewables-support rationales and instruments, see Fischer and Preonas (2010). For this article, it is irrelevant whether such policy objectives are sensible from an economic point of view; our model is independent of the exact interpretation of externalities.

[3] For an excellent survey of the theory of peak-load pricing, see Crew et al. (1995). For current applications of this model framework to electricity markets, see for instance, Borenstein and Holland (2005) or Joskow and Tirole (2007). Chao (2011) models renewable energy sources in a market with multiple intermittent electricity generation technologies. The focus is on socially optimal investment and different pricing schemes; externalities or their internalization are not part of the analysis.