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The potentials of a reverse auction in allocating subsidies for cost-effective roof-top photovoltaic system deployment

Dieter Mayr*, Johannes Schmidt, Erwin Schmid

Institute for Sustainable Economic Development, University of Natural Resources and Life Sciences, Feistmatelstrasse 4, A-1180 Vienna, Austria

HIGHLIGHTS

- Return-on-investment of PV varies by roof suitability, system size and subsidy level.
- A reverse auction for subsidies is a cost-effective mechanism for PV system deployment.
- Simulating a reverse auction for a case study region using a detailed solar cadaster and historical subsidy data.
- Results indicate electricity generation increases by up to 18% and reductions of public funding by up to 41%.

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ABSTRACT

Photovoltaic (PV) has developed to one of the most promising technologies for renewable electricity generation. The Austrian government currently provides subsidies for roof-top PV systems through a constant, administratively determined feed-in tariff or an investment co-funding. In both subsidy schemes, applications are approved on a first-come, first-served basis. There are concerns about (i) the selection of suitable roofs for PV systems, and (ii) allocating subsidies among applicants to deploy roof-top PV systems cost-effectively. Thus we analyze the potentials of a simple discriminative first-price reverse auction application scheme. Applicants define individually the required level of subsidy and those with the lowest request for subsidies are selected. In an ex-post analysis, we evaluate the potentials of such a scheme in increasing power output and saving public spending for the federal state of Vorarlberg in Austria. Results indicate a potential increase of cumulated produced electricity between 15% and 18% in comparison to the current policy. In addition, a reverse auction-based system would lead to savings of public spending per kWh between 20% and 41%.

1. Introduction

The European renewable energy directive 2009/28/EC requires member states to comply with the national targets (European Commission, 2009; Kettner et al., 2010). In Austria, solar photovoltaic (PV) is expected to achieve a cumulated installed capacity of 1200 MW by 2020 (Baumann and Lang, 2013). Over the last decade, PV has become an increasingly feasible and promising source of renewable energy due to technical progress and steadily decreasing installation costs. However, even though prices for PV modules are declining and market diffusion is increasing, the investment in PV systems without subsidization still remains unprofitable in Austria. This is evident from the fact that around 98% of all installed PV systems are subject to some kind of public co-funding in Austria (Biermayr et al., 2012).

A feed-in tariff (FIT) for PV electricity generation was first implemented in Austria in 2002. It has a similar design as the 'traditional' FIT in Germany: a constant, periodically updated, administratively defined tariff for a certain duration and system size. As concluded by Rickerson et al. (2007), the advantage of a FIT is that it enables a rapid and substantial growth in the renewable electricity markets. Furthermore, a FIT policy is also expected to have a positive impact on the creation of jobs and economic growth by promoting manufacturing industries. Consequently, more than 80 countries and jurisdictions around the world have adopted a FIT policy to promote PV (Wang and Cheng, 2012). Apart from the FIT, investment co-funding (ICF) has been implemented as a second support scheme for PV deployment in Austria. In this case, investors in PV systems receive initial financial support for the construction and installation of a PV system. A FIT subsidized PV system usually feeds all generated electricity into the grid, because the FIT tariff is higher than the end-user electricity price (see Table 3). Owners of PV receiving ICF, however, are incentivized to self-consume the generated electricity and sell the excess power to an electricity

* Corresponding author.
E-mail address: dieter.mayr@boku.ac.at (D. Mayr).

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Nomenclature

$I_{b,c,y}$	investment costs for PV system (€/kWp)
$CI^{FIT}_{b,c,y}$	real cash inflows in the period of guaranteed FIT in the REF scenario (€)
$CI^{FIT\_Rest}_{b,c,y}$	real cash inflows in the period of self-consumption and selling of electricity after the end of FIT payment in the REF scenario (€)
$CI^{ICF}_{b,c,y}$	real cash inflows in the period of self-consumption and selling of electricity in case of ICF funding in the REF scenario (€)
$CI^{POOL\_ICF}_{b,c,y}$	real cash inflows in the period of self-consumption and selling of electricity in case of ICF funding of buildings in the POOL of potentially high-yielding buildings (€)
$CI^{POOL\_FIT\_Rest}_{b,c,y}$	real cash inflows in the period of self-consumption and selling of electricity after the end of FIT payment for buildings in the POOL of potentially high-yielding buildings (€)
$CI^{REF\_Year}_{b,t,c,y}$	real cash inflows in a single year in the period of self-consumption and selling of electricity in the REF scenario (€)
$D_{b,c,y}$	decommissioning cost after life time (€)
$OMcost_{b,c,y}$	operation and maintenance costs (€)
$p^{FIT\_BID}_{b,c,y}$	bid of FIT subsidy (€/kWh)
$ROI^{FIT}_{b,c,y}$	return-on-investment of FIT subsidized photovoltaic (PV) systems in the REF scenario (%)
$ROI^{ICF}_{b,c,y}$	return-on-investment of ICF subsidized PV systems in the REF scenario (%)
$ROI^{REF}_{b,c,y}$	Return-on-investment of installed PV systems, either subsidized by FIT or ICF in the REF scenario (%)
$SUB^{ICF\_BID}_{b,c,y}$	bid of ICF subsidy (€/kWp)
$Y^{POOL}_{b,y}$	annual electricity yield of buildings in the POOL of potentially high-yielding buildings (kWh p.a.)
$Y^{REF}_{b,y}$	Annual electricity yield of buildings in the REF scenario (kWh p.a.)

Parameters

A_b	area available for PV installations on roofs of buildings (m²)
d	decommissioning cost in percent of investment cost (%)
$ep^{gross}_{t,c}$	gross electricity retail price (including net-fee, taxes, and other charges) (€/kWh)
eff^{mod}_{y}	module efficiency rate (%)
$ep^{sell}_{t,c}$	price for selling PV electricity to retailers (€/kWh)
eff^{sys}_{y}	system efficiency rate (including modules, inverter, losses due to outside temperature) (%)
i	annual inflation rate (%)
OM	annual operation and maintenance costs (in percent of investment costs) (%)
$p^{FIT}_{c,y}$	FIT subsidy (€/kWh)
Rad^{POOL}_{b}	annual solar radiation on the roof of buildings of the POOL of potentially high-yielding buildings (kWh p.a.)
Rad^{REF}_{b}	annual solar radiation on roof of buildings in REF scenario (kWh p.a.)
$SUB^{ICF}_{b,c,y}$	ICF subsidy (€/kWp)
$Sys\_price_{c,y}$	PV system prices (depending on capacity) (€/kWp)
tF	duration of FIT subsidy (years)
tL	life time of the PV system (years)
γ	rate of self-consumption of produced electricity (%)
η_t	annual losses due to degradation (%)

Subscripts

b	index of single buildings in each scenario (–)
c	system size group index (<5 kWp, 5–10 kWp, 20–20 kWp, >20 kWp)
t	time index (year)
y	year of installation (–)

retailer as market prices for selling electricity are usually much lower than for buying it (KLIEN, 2012). Until 2012, ICF and FIT were available for investments in PV in a mutually exclusive manner.

Three major concerns have arisen in the context of the Austrian subsidy policy. Firstly, as discussed in Lesser and Su (2008), it is difficult for policy-makers to define FIT attributes administratively, such as the level of the FIT tariff and its duration. Policy-makers are required to anticipate future market development and technological progress. Misjudgment could result in a cost-ineffective deployment of PV systems, while disproportional high subsidies can lead to avoidable windfall profits for investors, low subsidies might deter potential investors from investing in PV systems (Del Río, 2012). Similar information problems are relevant in the case of ICF subsidies as well. Secondly, there are concerns about the economic efficiency of subsidy allocation, if there is no competition. In traditionally more market oriented countries such as the UK, Australia or the USA, it is often argued that more competitive subsidy schemes, such as the Renewable Portfolio Standard in the USA or the Renewable Obligations Scheme in the UK, achieve a more cost-effective subsidization of Renewable Energy Technologies (RET) in comparison to the German-style FIT (Dong, 2012). Thirdly, there are serious concerns about the granting procedure for PV subsidies, such as in Austria. There, subsidies are currently approved via a web-based 'first-come, first-served' application procedure. Even though both subsidy schemes (FIT and ICF) require certain regulations with respect to size, material or installation of PV systems, there are no regulations governing the decision which roof is eligible for subsidization or whether a roof is even suitable for PV electricity generation. Furthermore, PV subsidies are usually awarded within minutes after opening the application procedure, thus implying that there is a high demand for PV subsidies (KLIEN, 2012; OeMAG, 2012a).

Therefore we propose the use of a reverse auction to allocate subsidies for a cost-effective deployment of roof-top PV system. Reverse or procurement auctions are common for support of public procurement (De Silva et al., 2008; Nakabayashi, 2013) and environmental services (Greenhalgh et al., 2007; Jindal et al., 2013). In such an auctioning procedure, one buyer faces many sellers, who are bidding their services at the lowest possible price (Giebe et al., 2006). Laffont and Tirole (1993) argue that, in a reverse auction, competitive bids can be elicited, when several applicants are possible candidates to realize a project. Thurston et al. (2010) have analyzed a reverse auction for the implementation of distributed stormwater management practices in Shepherd Creek, USA. There, home owners were invited to participate in a reverse auction to receive public funding for the installation of either rain barrels or rain gardens. The auction procedure is assumed to achieve efficiency, objectivity, transparency and flexibility in the allocation of public funds, as those investors who are situated to make the best use of funding, are selected. Furthermore, prices are determined by the market and not by a governmental agency. The rules in bidding for and granting subsidies are