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Optimising feed-in tariff design through efficient risk allocation

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ABSTRACT

Many Feed-in Tariff designs exist. This paper provides a framework to determine the optimal design choice through an efficient allocation of market price risk. Feed-in Tariffs (FiTs) incentivise the deployment of renewable energy technologies by subsidising remuneration and transferring market price risk from investors, through policymakers, to a counterparty. This counterparty is often the electricity consumer. Using Stackelberg game theory, we contextualise the application of different FiT policy designs that efficiently divide market price risk between investors and consumers, conditional on risk preferences and market conditions. Explicit consideration of policymaker/consumer risk burden has not been incorporated in FiT analyses to date. We present a simulation-based modelling framework to carry this out. Through an Irish case study, we find that commonly employed flat-rate FiTs are only optimal when policymaker risk aversion is extremely low whilst constant premium policies are only optimal when investor risk aversion is extremely low. When both policymakers and investors are risk averse, an intermediate division of risk is optimal. We provide evidence to suggest that the contextual application of many FiT structures is suboptimal, assuming both investors and policymakers are at least moderately risk averse. Efficient risk allocation in FiT design choice will be of increasing policy importance as renewables deployment grows.

1. Introduction

The intermittent nature of many renewable energy sources combine with uncertain market prices to make renewable energy investment an inherently risky venture. Feed-in Tariffs (FiTs) guarantee a set payment per unit of electricity generated and thus limit investors' exposure to low market prices to a greater extent than alternate mechanisms [1–5]. Although theoretically less efficient than quantity-based schemes [6], FiTs have become a preferred policy mechanism for many jurisdictions as the reduced exposure to market price risk has incentivised greater deployment of renewable technologies [2,7].

FiTs do not eliminate market price risk but rather transfer this risk to a counterparty. This counterparty bears the risk of additional policy cost if wholesale prices are less than the FiT guarantee. Often, a policymaker incurs this aggregate risk in the first instance, which is then transferred to electricity consumers through additional charges on consumption [8,9]. Different FiT designs apportion this risk in different ways [10,11], with zero, partial or full transfer of market price risk possible [12]. Although the literature has acknowledged that appropriate risk transfer is central to successful renewables policy [13], the optimal division of risk has not been analysed.

Given both investor and policymaker aversion to market price risk, optimal policy design must efficiently divide this burden, analogous to the division of risk central to the design of insurance contracts [14]. This paper presents a simulation-based modelling framework to divide risk in a similar way. To carry this out, a characterisation of both investors' and policymaker's/consumers' attitude to market, regulatory and policy risks, and their reactions in

Abbreviations: CARA, Constant Absolute Risk Aversion; CE, Certainty Equivalent; CfD, Contract for Difference; CRRA, Constant Relative Risk Aversion; EMV, Expected Money Value; FiT, Feed-in Tariff; IEA, International Energy Agency; MW, Megawatt; OECD, Organisation for Economic Cooperation and Development; O & M, Operations & Maintenance; REFIT, Renewable Energy Feed-in Tariff; ROC, Renewables Obligation Certificate; SEM, Single Electricity Market; VWAP, Volume-Weighted Average Price; CP, Constant Premium; SU, Shared Upside; CF, Cap & Floor.

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different contexts, is required [9,15]. This is an important contribution, as while many policy designs have been implemented to date, the choice has not been guided towards the most efficient outcome through an appropriate objective framework. This framework is developed in this paper and applied to an Irish case study. This gives important policy insight as the impact of excessive consumer exposure to market price risk is becoming of increasing concern for FiT policy in many countries such as Ireland [8], Germany [16], the UK [17] and Italy [18].

This paper is structured as follows. The following section will give a literature review. Section 3 will outline the methodology employed. Section 4 presents the data for a stylised Irish case study while Section 5 describes the results. Finally, Section 6 offers a discussion and conclusion.

2. Literature review and motivation

A considerable gap exists in the literature to provide a suitable policy tool to identify the optimal FiT design. Reviewing the literature in this field brings together literature focusing on investment incentives and consumer policy cost. Much of this analysis is from an investor's perspective and has compared investment incentives created by FiTs with those offered by alternate, non-FiT support mechanisms [4–7,19]. The literature to date has found that FiTs have led to greater deployment than alternatives as investor exposure to market price risk is lower [1,20–22]. Indeed, exposure and attitude to risk is a key determinant in the superior effectiveness of FiT regimes. Comparing FiTs to quantity-based policies, Fagiani et al. [5], Kitzing et al. [23] and Kitzing [21] have emphasised the importance of incorporating market price risk when deciding on the subsidy type (in particular, a FiT or quantity-based mechanism). Indeed, Dinica [24] and Feng et al. [25] elaborate on how the relationship between risk and profitability is key to encouraging investment.

While the preceding papers have stated the importance of considering risk for the superior effectiveness of FiT mechanisms, focusing on risk attitudes and investment incentives in optimal FiT design has received less attention in the literature. Kim and Lee [11] have analysed FiT payout structures to incentivise Solar PV deployment. Kim and Lee [11] incorporate network effects and the propensity to adopt household-based solar PV. However, they do not evaluate how different attitudes to market price risk may affect results. Doherty and O'Malley [26] also focus on investors when analysing the efficiency of Ireland's FiT design. Although they suggest that the current Irish FiT over-remunerates investors, they do not compare FiT choice amongst efficiently specified options, nor do they consider consumer and investor attitudes to market price risk. Farrell et al. [12] provide a model with which different FiT regimes may be efficiently defined using option pricing theory. For each design, cost and remuneration are equal in expectation. However, the balance of certain/uncertain policy cost and investor remuneration varies between policy options.

Although managing investor risk exposure has been found to be of great importance for optimal energy policy, less attention has been given to managing policymaker/consumer risk exposure. However, a body of literature exists to analyse trends in policymaker/consumer cost. Parkinson and Djilali [27] discuss the issue of performance uncertainty of energy technologies with respect to pollution limitation, and the incorporation of policymaker risk aversion in prudent policy design. In an Australian context, Riesz et al. [28] consider the risks of excessive policy cost associated with adopting high levels of gas penetration to abate carbon emissions. Leepa and Unfried [29] discuss the impacts of overdeployment and how this may result in excessive consumer cost. Low market prices present a similar risk of excessive consumer cost in relation to FiT policies. Indeed, a greater penetration of renewables coupled with lower than expected fossil fuel cost has resulted in greater subsidies in recent years [8,17,30,31] with potential for this trend to continue [5,13,17,29,31–33]. One can see that increasing policy cost is a consistent trend, with uncertainty regarding the extent of future policy cost [13,33]. Given that the setting of a FiT policy is carried out in a prospective manner, where future costs are uncertain, the incorporation of consumer burden and attitudes to risk of excessive policy cost is an important consideration.

Thus, it is important to correctly manage both investor and policymaker exposure to market price risk when designing renewables policy. Such management involves balancing a trade-off: removing one degree of market price risk from the investor requires the policymaker to bear an additional degree of risk. Precisely identifying the most efficient point in this trade-off has not been carried out by the literature to date.

Farrell et al. [12] discuss the concept of risk-sharing when choosing between designs using a bi-level model similar to that considered in this work. In particular, they discuss the Value-at-Risk (VaR) associated with different policies ex-post any FiT level decisions made. However, when determining optimal FiT levels, they model both policymakers and investors as risk neutral players. Thus, in contrast to this paper, they do not explicitly incorporate the risk preferences of either policymakers or investors into their respective decision-making problems. Consequently, this paper provides a number of important contributions for policymakers when considering the most appropriate Feed-in Tariff choice:

1. The policymaker's preferences are less dominant than those of investors when degrees of risk aversion are of a similar magnitude.
2. Market price risk should be shared except under circumstances of extreme investor/consumer indifference to risk.
3. Shared upside policies offer very similar levels of utility to cap & floor policies (see Section 3.2 for a detailed description of the FiTs considered in this work). However, when policymakers are extremely risk averse and investors are modestly risk averse, the expected cost of the cap & floor policy is slightly smaller.
4. When policymakers are risk averse and investors have low levels of risk aversion, constant premium policies offer higher utility when compared shared upside policies. However, in Expected Money Value (EMV) terms, constant premium policies are always more expensive.

The efficient division of risk is also common in other contexts. For instance, Raviv [14] show that an optimal insurance contract may be designed by first identifying the insured's optimal level of coverage as a function of the insurance premium and then identifying the optimal premium from the insurer's perspective. Mahul [34] apply a similar framework to identify how weather-dependent production may insure against climate risks, whilst Ma and McGuire [35] model the design of optimal health insurance contracts. The following section presents a tool with which policymakers can identify the optimal point in this trade-off when choosing a suitable FiT policy structure.

3. Methodology

The methodology of this paper consists of three steps. First, we model electricity market prices. Second, we specify efficient FiT specifications which allow for investor remuneration/policy cost to be identified. Third, these cost/remuneration calculations are used alongside a model of risk averse investment to determine an optimal FiT design conditional on risk preferences. These steps will be outlined in turn in this section. FiTs transfer risk from investors, through policymakers, to consumers. To aid the discussion that follows, we refer to policymaker burden alone. However, this may be interpreted as a collective term for the total burden incurred by all consumers. Tables 1–4 display the indices, parameters, functions and decision variables of the overall model respectively.