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Risk aversion and CO_2 regulatory uncertainty in power generation investment: Policy and modeling implications

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ABSTRACT

We consider a simulation of risk-averse producers when making investment decisions in a competitive energy market, who face uncertainty about future regulation of carbon dioxide emissions. Investments are made under regulatory uncertainty; then the regulatory state is revealed and producers realize returns. We consider anticipated taxes, grandfathered permits and auctioned permits and show that some anticipated policies increase investment in the relatively dirty technology. Beliefs about the policy instrument that will be used to price carbon may be as important as certainty that carbon will be priced. More generally, a failure to consider risk aversion may bias policy analysis for the power sector.

1. Introduction and motivation

Regulation of the power sector to protect the global climate seems likely at some point in the US, and anticipated costs are large relative to past regulatory interventions. We consider risk-averse investors planning to expand electricity generation capacity given uncertain future regulation of carbon dioxide emissions. We allow investors to anticipate different kinds of policies, and we consider the implications of their investment choices for outcomes in the presence and absence of the anticipated regulation. Numerical results from a stochastic two-stage equilibrium model suggest that in the presence of risk aversion, some policy instruments will introduce perverse incentives favoring investment in dirty generation technology. In particular, permit allocation decisions have strong impacts on profits and risk. Thus the choice between grandfathering and auctioning emissions permits has implications for efficiency and costs, as well as the usual distributional effects.

Investments in generation capacity have lasting consequences for costs and emissions. The median coal-fired generation facility in the United States is over forty years old [1]. There are significant fixed costs to building capacity, and switching a given plant from one fuel to another is usually expensive or impractical. Risk is increasingly important in this setting, and thus analyses that assume certainty (or the ability to switch from one stream of annualized power plant costs to another at zero or low cost) can be misleading. Financial hedges in this setting are also limited due to difficulties in credit markets, and investor reluctance to insure firms against downside risks that are likely to correlate with significant economic costs and to affect most firms in this setting simultaneously [2–4].

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In particular, risk-averse decision makers facing uncertain regulation may make investment choices that lead to a persistently inefficient generation mix for the decades ahead. Reinelt and Keith [5] find that the "interaction of regulatory uncertainty with irreversible investment raises the social cost of carbon abatement by as much as 50%" with risk-neutral investors[1]. Uncertainty can lead to investment in dirty technology in hopes that future policies will favor owners of existing coal plants, or to support lobbying efforts designed to minimize regulation. This overinvestment is socially suboptimal; it may also be suboptimal for business interests relative to a setting in which it is known with certainty whether or not there will be regulation. We examine the effects of incorporating risk aversion in profits as well as uncertainty regarding regulation, and consider some implications for the broader policy debate and associated modeling efforts.

The two-stage model considers investments by two types of firms, one building highly polluting but low variable cost capacity (coal-fired plants), and the other building low polluting but high variable cost capacity (natural gas plants). Our efforts focus on the changing incentives for each kind of investment and are not an effort to realistically depict a single firm's investment portfolio; given homogenous technology, allowing multiple firms to invest in both technologies will yield identical choices across firms, which complicates exposition without adding new insights. Firms with the capacity to hedge two technologies against each other will have different responses to regulatory uncertainty than those that cannot, but the change in price and cost ratios will work in the same direction for each type of investment. The first-stage investment decision is made in the face of regulatory uncertainty as to whether or not a given carbon policy will be imposed. In the second stage, the regulation is either imposed or not, and a short-run market equilibrium among the firms results. Price-taking behavior is assumed throughout.

We consider a carbon tax, a cap-and-trade system with initial allowances auctioned, and a cap-and-trade system where permits are grandfathered to generators. As expected, regardless of how the allowances are allocated in a cap-and-trade system, risk-neutral firms make the same decisions in terms of capacity and output, even though different allowance allocation and distribution schemes yield varying profits. Risk-neutral firms choose an investment mix that is optimal for neither policy, maximizing the expected payoff of investment strategies based on their beliefs about the likelihood of the regulatory regime. Risk-averse investors hedge their bets to reduce their losses in the 'bad', low profit outcome even more than expected profit maximizers. In the case of a tax or an auctioned permit scheme, the bad outcome is regulation, and when permits are grandfathered it is no regulation.

As intuition suggests, risk-neutral suppliers facing possible regulation build more gas and less coal-fired generation capacity than in a business-as-usual (BAU) no regulation scenario, regardless of what form the potential carbon regulation takes. Risk aversion complicates matters: if allowances are grandfathered, risk aversion increases investment in coal – which pays off in the bad, unregulated state – and decreases it in gas relative to the risk-neutral solution. If allowances are auctioned, the reverse is true. This result is driven by the gains from increased distribution of free permits to coal plants under grandfathering. Under our parameterizations, coal plant profits are higher under regulation, broadly consistent with observation of the European Union Emissions Trading System [6]. In contrast, an auction or carbon tax provides a more direct signal to reduce emissions: firms see the rise in the expected relative price of coal-fired generation under regulatory uncertainty and the more risk averse they are, the more they invest in less carbon-intensive generation that will pay off in the regulated state.

This analysis focuses on firms that are uncertain about the passage of a specific regulation. It seems natural as well to consider the uncertainty about the form of eventual regulation, including uncertainty regarding the details of permit allocation and distribution schemes. We have formulated and solved models representing the situation in which firms are uncertain about the form of regulation. This limits the ability of firms to hedge regulatory risks by adjusting investment strategies, and thus the effects of risk aversion are mixed and small relative to the results presented here.

2. Related literature

It is difficult to observe levels of risk aversion and risk management strategies empirically[2] , and we are not able to determine how risk-averse power operators and investors are. However, our results suggest that modest amounts of aversion to risk that are hedged via investments in durable physical capital will impact the ability of the US power sector to meet emissions goals efficiently.

In most of the literature on electricity market modeling as well as on carbon policy in particular, firms' risk attitudes are not captured. Models common in this setting, e.g., NEMS [9] and IPM [10] are deterministic. They assume a single regulatory scenario and perfect foresight. This reflects the extreme complexity of these models. Here we have simplified much that is important in policymaking to focus on the implications of risk aversion in isolation.

We believe this investigation to be useful and relevant; Niemayer [11] shows that older and dirtier coal plants are especially vulnerable to changes in carbon emissions rules over the next five to ten years, and this trend seems unlikely to change. Barbose [12] investigates the plans of western utility companies and shows that most of them currently make

[1] Their calculations do not allow for the possibility of retrofits for conventional plants.

[2] Chetty and Szeidl [7] and Chetty [8] show how consumer insurance choices, for instance, are insufficient to deduce levels of consumer risk aversion, and firm insurance strategies cannot generally be observed to any significant degree.