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Information aggregation in a prediction market for climate outcomes

Elmira Aliakbari [a], Ross McKitrick [b,*]

[a] Fraser Institute, Vancouver, BC, Canada
[b] Department of Economics, University of Guelph, Guelph, ON, Canada

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ABSTRACT

Two forms of uncertainty in climate policy are the wide range of estimated marginal costs and uncertainty over credibility of rival information sources. We show how a recently-proposed solution to the first problem also helps address the second. The policy is an emissions tax tied to average temperatures, coupled with permits that exempt the emitter from paying the tax in a future year. It has been shown that the resulting tax path will be correlated with future marginal damages. It has been conjectured that the permit prices will yield unbiased forecasts of the climate, which, if true, would address the second uncertainty. We confirm the conjecture by describing a trading mechanism that converges on unbiased forecasts if traders are risk-neutral. Risk aversion slows down but does not prevent convergence. We also show that the forecasts are more likely to be sufficient statistics the stronger the consensus on climate science.

1. Introduction

A policymaker wanting to address the climate change issue faces many information problems. This paper examines novel solutions to two of the most acute: uncertainty regarding marginal damages of greenhouse gases, and incomplete or biased selection of information for presentation to policymakers. The first derives in part from scientific uncertainty over Equilibrium Climate Sensitivity (ECS), which is defined as the projected long term climate response to doubling the concentration of CO2 in the atmosphere, after enough time has passed for all components of the climate system to adjust. A widely-used study by Roe and Baker (2007) yielded an ECS distribution with a 5th percentile of 1.72 °C and a 95th percentile of 7.14 °C (IWG 2010). Applying this distribution and a 3% discount rate, Integrated Assessment Models (IAMs) generate a range of marginal damage estimates spanning -$22 to $727 per tonne of CO2 (IWG, 2013). Hence, based on mainstream climate and economic modelling, the optimal climate policy seems to lie somewhere between a small subsidy for, and an effective ban on, all emissions—a rather unhelpful state of affairs to say the least.

Past attempts to reduce the uncertainty of climate policies are reviewed in Section 2. The approach considered herein involves a temperature-indexed carbon tax (McKitrick, 2011) that presents emitters with a dynamic pricing rule rather than a commitment to a specific price path. On an ex-post basis, the rule yields a price path highly correlated with the unobservable true marginal damages trajectory, thus contributing to resolution of the first form of uncertainty, since firms subject to the tax must form unbiased expectations about future values and plan accordingly. A proposed modification to the policy instrument can also address the second information problem. To facilitate expectations-formation, Hsu (2011) proposed pairing the tax with a sequential futures market for tradable certificates, each of which would exempt the holder from paying the tax on a tonne of emissions in a specified future year. He conjectured that since firms have a financial incentive to get the forecasts right, the price path thus generated would provide the most objective and informative forecast of future marginal damages and, by implication, future climate warming, since investors will have an incentive to use all available information, i.e. to avoid cherry-picking.

This paper is concerned with the conditions under which the permits trading mechanism would yield informative and unbiased forecasts of future climate states. We refer to the temperature-indexed pricing rule as a state-contingent carbon tax, and the trading system as a futures market for exemption permits. Since projected damages are expected to occur rather far in the future, they cannot be directly measured and will depend strongly on the modeler's choice of ECS,

* Corresponding author.
E-mail address: ross.mckitrick@uoguelph.ca (R. McKitrick).

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among other parameters. Policymakers must therefore rely on damage estimates that rest on expert opinion, which raises the possibility of bias since scientists will be aware that their parameter selections have implications for policy outcomes over which they may have preferences (Johnston, 2012, InterAcademy Council, 2010). A prediction market that generates a state-contingent carbon tax path based on expectations among agents who have a financial incentive to get their forecasts right would potentially resolve this problem by creating an incentive to form unbiased climate projections. An ideal auction price should therefore be both an unbiased estimate of the actual future price (and hence the actual future climate state), and also a sufficient statistic (making efficient use of all available information).

We model a prediction market implementing the McKitrick (2011) and Hsu (2011) state-contingent carbon tax/prediction market system in an auction framework developed by Kyle (1985) and Foster and Viswanathan (1996, herein FV96). Three types of traders are assumed to participate. Risk-neutral firms subject to the emissions tax are assumed to have private access to noisy signals about the likely future climate state and hence the likely future tax rate, and to make bids for permits based on their profit-maximizing strategies. Also, an unspecified number of uninformed traders generate noise in the market by trading based on purely random signals about the future climate state rather than informative private signals. A market maker who only sees the aggregate order flow but does not observe individual bids or the number of uninformed traders clears the market in each round of bidding, thereby generating a price signal which is incorporated into information sets by traders in subsequent trading rounds.

Interestingly, this trading set-up corresponds to that of a newly-proposed climate prediction market to be run by a UK-based financial firm (Winton Capital, 2017). Traders will be able to buy and sell securities whose underlying value will be tied to future values of publicly-available global temperature measures. Though there is no state-contingent policy needing to be hedged, the market designers were motivated by concerns that biased information interfered with optimal policy planning, asking: "Are peoples' positions driven by what they want to be true or what they believe to be true?" (Winton Capital, 2017) The proposed market allow informed and uninformed people to trade certificates tied to future climate states, with Winton acting as a non-profit market maker.

Our paper provides some evidence that such a market will in fact aggregate information in a useful way. Employing a proposition due to FV96 we confirm part of the conjecture of Hsu (2011) for the case of risk-neutral traders: such a prediction market would yield an unbiased forecast of the future tax rate, and hence the state of the climate. It is less clear that the prediction market will use all available information efficiently. Interestingly, one's belief about the level of consensus around climate science strongly influences one's interpretation of the market outcome. The question of the degree of consensus in climate science, and what specific points experts actually agree on, is itself controversial (Berry et al., 2016; Tol, 2014). We treat the notion of scientific consensus as corresponding to a high level of correlation of informed traders' signals, and hence of their beliefs. In other words, a strong scientific consensus means that regardless of the source an informed trader draws upon, it is the same information as other traders are receiving. We find that, even in the presence of noisy uninformed traders, the market price will converge to a sufficient statistic (in other words, an expectation that efficiently uses all available information) if, at the start of trading, private beliefs of informed traders are highly correlated, or in other words, if there is a truly strong consensus on the scientific issues, so that traders seeking credible information are effectively drawing the same signals regardless of source. In this case, the trading process we describe will yield a price path that incorporates all relevant information and no trader would be able to improve on the market price forecast using his or her private information set. Conversely, to argue that the prediction market outcome fails to take account of some relevant information about the future path of the climate requires an assumption that there is no current consensus about climate science.

The FV96 framework assumes traders are risk-neutral. We extend the theory by allowing firms to be risk-averse. We show that risk-aversion slows down the convergence process, so the market outcome is more susceptible to the influence of uninformed traders.

Prediction markets were first proposed in 1988 by researchers at the University of Iowa interested in predicting US presidential outcomes (Segol, 2012). The markets were designed based on the informational role of prices and the efficient market hypothesis suggested by Hayek (1945) and Fama (1970). They are not magic devices for generating error-free information about the future, since they are still susceptible to all the biases, wishful thinking and other forms of irrationality that enter human judgment. Their advantage is that they create a financial incentive for participants to be objective and to use all available information, and this leads us to ask how they might be harnessed to yield unbiased and efficient climate forecasts. Although market efficiency assumptions have been exposed to some critiques, especially from behavioral economists, other researchers (Wolfers and Zitzewitz, 2004; Berg et al., 2008) have shown that prediction markets perform well and generate accurate forecasts. A recent survey by Graefe (2016) compares prediction markets to a variety of polling and prediction methods in international elections and shows that they consistently provide the most accurate forecasts (even though, as noted in Graefe, 2017, they can still fail, as they did in the Brexit and US 2016 Presidential election cases). This motivates our interest in using them for predicting climate change, which is an application of considerable international importance.

Recent work by Atakan and Ekmekci (2014) has shown that a common-value market may fail to aggregate information if the buyers must simultaneously choose an action, the bid payoff is jointly determined by the action chosen and the state of the world, and the price of the object is independent of the state of the world. In our set-up buyers do not commit to any action other than holding the permit, the value of which is fully determined by the state of the world independent of any subsequent action chosen by a bidder. Consequently, the failure of information aggregation in Atakan and Ekmekci (2014) does not occur in our model. However, if the policy game herein were modified such that every bidder must simultaneously commit to an action to be taken after each auction, the value of which would depend on the state of the world after the price is revealed, then we would need to take into account the possibility that an equilibrium may emerge in which no information is aggregated.

The assumed damage function underlying our model is continuous (see Assumption 4 in McKitrick, 2011) as is typically assumed in climate policy models. Lemoine and Traeger (2012, 2016) have explored a model with one or more potential discontinuities in the state function, reflecting concerns about possible "tipping points" or bifurcations in the climate system at which an irreversible transition to a new state function takes place. Such tipping points are associated with changes in the pollutant stock (concentration), which is a heavily smoothed function of annual emissions in the case of carbon dioxide. The possible existence of a future tipping point, the timing until it is encountered, and the magnitude of the discontinuity it might impose, are additional forms of uncertainty that we do not address herein. The prediction market we propose may help reduce these uncertainties since traders will profit from correctly anticipating any form of change in the state variable, but establishing this formally is beyond the current limits of our analysis.

The paper is organized as follows. Section 2 provides the literature review on this topic. Section 3 presents the model, assumptions, and definitions. Section 4 describes the linear equilibrium of the model and its necessary and sufficient conditions. Section 5 presents the results. Section 6 extends the existing model to include risk aversion and the final section briefly summarizes the conclusions.