Prediction-market innovations can improve climate-risk forecasts

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Forward-looking information about climate risks is critical for decision makers, but the provision and accuracy of such information is limited. Innovative prediction market designs could provide a mechanism to enhance applied climate research in an incentive-compatible way.

Organisations now appreciate that, when making strategic plans, they must consider climate-related risks [1]. These include *physical* risks, associated with warming, and *transition* risks, arising from the decarbonisation of the economy. Forward-looking information about these risks is needed to make decisions and disclose risks to stakeholders. The Task Force on Climate-Related Financial Disclosures (TCFD) has developed a framework that has inspired mandatory disclosures in several countries [2]. In 2022, the U.S. Securities and Exchange Commission proposed disclosure requirements modelled on the TCFD framework [3].

TCFD recommends that organisations assess their resilience under different climate scenarios, such as those from the IPCC or NGFS. However, these scenarios typically do not include all required variables or do not provide them at sufficient granularity. "Scenario expansion" aims to fill the gaps in a climatologically consistent way. Uncertainty over the likelihood of scenarios, combined with uncertainties in climate under given scenarios, creates a cascade of uncertainty down to variables that impact organisations, such as sea-level or crop yields. Decisions that incorporate these compounded uncertainties can be very different from those under either a "most likely" or "worst case" scenario.

There is an emerging ecosystem of climate information providers, which includes academia, government, NGOs, and private sector climate service providers (CSPs). While any increase in climate expertise is welcome, it accentuates several structural problems with the provision of climate information that should be addressed: (i) its multi-disciplinary nature, (ii) the “circularity problem”, (iii) evaluation of long-range forecasts, and (iv) incentives that providers and users of forecasts may have to exaggerate or down-play risks.

(i) Predicting climate is a multi-disciplinary problem: forecasting climate *given* the concentration of greenhouse gases (GHGs) requires expertise in physical sciences while predicting future GHG concentrations needs expertise in economics, policy, and innovation. IPCC predictions are contingent on socio-economic scenarios, obviating the need to fully integrate physical and social sciences but creating an information gap regarding the likelihood of scenarios. One consequence of this gap is an overrepresentation of studies involving the high emissions RCP8.5 scenario, regarded as implausible by some researchers [4]. Overemphasising RCP8.5 overstates physical risks, but also downplays transition risks. Furthermore, studies show that researchers faced with the same data can come to different conclusions by making different methodological choices [5,6], so relying on a single source is riskier than integrating multiple perspectives.

(ii) Future climate depends on emissions reductions, which themselves will depend on predicted climate [7]. In the context of inflation forecasting this has been dubbed “circularity” [8,9]. If a climate forecast suggests only modest future warming, this could be because the estimated climate sensitivity is low or, it could imply an expectation that emissions will be curtailed. Policy makers need to differentiate these interpretations.

(iii) Forward-looking climate information has a long “discovery time” to ascertain its accuracy. Short-range weather forecasts have a discovery time of days, so a track record can be used to assess skill. When discovery times are years, or decades, it is difficult to evaluate quality. Users may be unwilling to pay for quality they cannot verify, so R&D investments may not be rewarded. Markets with such information asymmetries can experience a decline in the quality of products and even market failure [10].

(iv) Organisations using climate information might not prioritise accuracy, preferring to minimise their *perceived* exposure to climate risks. Such behaviour is not hypothetical: in the early 2000s issuers of mortgage-backed securities “shopped around” rating agencies to secure investment-grade ratings. The subsequent proliferation of inaccurate ratings contributed to the subprime crisis of 2007 [11]. If CSPs operate under similar incentives, evaluations of climate risk might also be systematically inaccurate.

As the demand for long-range climate information increases it is important that the problems outlined above are addressed; prediction markets offer a means to do so.

Prediction markets are designed to aggregate information, rather than allocate capital or transfer risks. They often use “Arrow-Debreu” securities which pay a fixed amount if a specified event occurs. Participants trade these contracts and, if the market is well designed, the prevailing price of a contract can be interpreted as a “market-based” probability for the event [12].

One of the earliest prediction markets, now known as the Iowa Electronic Markets (IEM), was created in 1988. IEM has focused on predicting election outcomes, outperforming opinion polls [13]. Prediction markets using expert participants have also predicted whether psychology studies would replicate. These markets outperformed simple surveys and surveys weighted by expertise [14]. Markets to predict and hedge climate change have been discussed [15,16,17], but no long-range markets for climate have been established due to regulatory obstacles, the need to attract participants with divergent views, the circularity problem, and the necessity of creating institutions with the required longevity.

Prediction markets in which participants pay to take part are typically classified as gambling, making them illegal, or regulated, depending on the jurisdiction. But prediction markets can differ from traditional gambling in that participants are not intended to be a source of revenue but a source of information; this distinction enables them to be operated in new ways.

Rather than staking money, participants could be granted credits representing a share of funding provided by sponsors seeking information. A subsidised market does not need uninformed "noise" traders to reward informed traders. Incorrectly assuming uninformed traders will participate and subsidise information discovery can result in markets that are too thinly traded to provide useful information. Although noise traders subsidise information discovery, they also inhibit it when trading in a correlated yet uninformed way. Instead, an automated market maker can be used to ensure liquidity. The market maker will always trade at prices determined by the relative popularity of outcomes. Its pricing algorithm can reward participants according to an incentive-compatible scoring rule [18]. If a participant believes the probability of an outcome is higher than the quoted price, they have an incentive to buy, while if they think it less probable, they should sell. Participants maximise expected rewards by trading based on their true beliefs. Instead of being gambling, such markets are akin to collective consultancy with performance-based rewards.

"Circularity" can be addressed with joint-outcome markets: e.g., a market can simultaneously predict GHG concentrations and global temperature, generating an implied joint probability distribution from which a transient relationship between GHGs and temperature can be inferred.

Prediction markets could synthesise the expertise of climate information providers into probability forecasts of climate-related variables of interest to decision makers. These markets could be much more than a gamification of climate forecasting; they could be an innovative mechanism to efficiently distribute funding for applied climate research in an incentive-compatible way.

Markets could be sponsored by consortia with common information needs. Additionally, public sector and philanthropic organisations could sponsor markets to produce forecasts as a public good. Because markets would be subsidised, participation would need to be limited and the selection criteria would be a sensitive issue. Initial participation could be restricted to groups already providing advice to policy makers. Even with this restriction, markets could provide a structured way to aggregate the views of these groups and produce forecasts with lower errors than other methods [19]. As policy makers become more familiar with the approach, participation should be widened to take full advantage of the ability of markets to aggregate diverse sources of information. With changes to regulation, paying participants could even take part alongside invited participants. The names of participating organisations should be public to show that diverse views are being incorporated. If competing prediction markets arise, arbitrageurs could push them towards consistency, preventing users from cherry-picking forecasts, as they can with individual providers.

Prediction markets cannot be settled until the outcome is known and this could be decades in the future. Although this horizon is significantly longer than existing prediction markets it is not exceptional compared with other contracts, such as mortgages and pensions. People pay attention when consequential sums of money are at stake and, to attract and maintain interest in long-range prediction markets, subsidies must be commensurate with the effort expected from participants. Establishing markets over multiple horizons and allowing interim selling and withdrawals would help maintain engagement. Long-range markets require robust governance, including segregating funds so participants are confident they will be paid at settlement. Interest accrued by these segregated funds should be reflected by an appreciation in the value of the credits in which markets are denominated.

If structural problems with the current market for climate information are not addressed, it will be vulnerable to adverse selection, or even outright failure, with lower-quality information crowding out higher-quality information. This could be exacerbated if users deliberately favour biased, or unduly precise, assessments of climate risks. Prediction markets can mitigate these problems by aligning the incentives of providers and aggregating diverse sources of information and expertise into collective forecasts of future climate risks.

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