Impacts of Climate Policies on Energy Security in Carbon-restrained China

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Energy security, as a conventional and indispensable constituent of economic security, has long been a top research priority, and the dynamics of energy security become particularly complicated with the involvement of climate change, especially for the security of 'vital vulnerability of vital energy systems.' Climate change may worsen the spatial imbalance of energy supply and demand, and cause the conventional energy market to fluctuate more frequently and extensively, which would heavily increase the cost risks of the entire economic system. In contrast, climate change affects the resilience of the energy system itself and energy-related infrastructures, which, in turn, makes the energy system more vulnerable (Farrell et al., 2006; Jewell et al., 2016). As a result, energy security further features its added acceptability, given the increasingly stringent situation of global warming (Sovacool & Brown, 2010).

As the largest greenhouse gas (GHG) emitter and energy consumer, China is facing more overwhelming and pressing challenges in climate change and energy security than any other country, which enhances the high importance of studying the possible relations between China's climate policy and energy security. Theoretically, we first incorporated the possible emission budgets across various emission allocation principles under the 2-degree warming-limit target into a 3E-integrated model. Then, we developed a systematic simulation and analysis framework by examining a series of energy security metrics. Empirically, our emphasis is primarily on exploring the potential unidirectional consistency between climate change and energy security that has been found at the global level, i.e., investigating the dynamic long-term impacts of climate policies on energy safety. Additionally, analyzing the macroeconomic costs and energy security co-benefits of climate policies is also one of our research centers.

The implementation of the entire empirical simulation, which includes the outputs of energy, economy and emissions, and the consideration of climate policies, primarily depended on the Chinese single-sector 3E-integrated assessment model, CE3METL. This model is a Chinese version of the global E3METL (Energy-Economy-Environmental Model with Endogenous Technological change by employing Logistic curves), which is lead-developed in 2013 by H. Duan (Duan et al., 2013; 2015). With the simulation outputs of CE3METL, we further build an effective metric system to evaluate China's long-term energy safety. The most representative indicators were well considered, covering energy and oil intensity, per capita energy and oil consumption, energy and oil expenditures, and energy diversity (Shannon-Weiner Index, SWDI).

The 2C warming-limit target (above pre-industrial levels) has been established as one of core tasks of the Paris agreement, which implies that the future emission budget is limited and we are striding into the times of emission control. As the most recent study reveals, if we want to prevent the global temperatures from exceeding the 2-degree threshold with a probability higher than 50%, then the cumulative carbon space from 2011 to 2100 ranges from 990 to 1,450 giga tons of carbon dioxide ($GtCO_2$). We could theoretically obtain the corresponding cumulative emission space for any specific country given the global emission budget under the 2C warming-stabilizing goal (Raupach et al., 2014), and the national-level budgets of GHG emissions play a significant role in guiding short-term emission control activities and the long-term design of emission reduction targets, particularly for China. Based on the existing estimations on regional emission constrains, we designed 6 scenarios in total, including a reference scenario and 5 emission control policy scenarios, i.e.,

BAU **B**usiness-**A**s-**U**sual: keeping the current trends of economic growth, energy consumption and technological change, no special climate policies are incorporated.

INDC **I**ntended Nationally **D**etermined **C**ontributions: taking emission constrains into account, and carbon tax policy is endogenously introduced for achieving China's committed carbon-peaking goal in 2030.

Inertia Emissions **Inertia** (Grandfathering): considering endogenous carbon tax policy, and the available emission budget is estimated by so-called inertia principle under the 2-degree warming threshold.

In&Eq Blend of **In**ertia **& Eq**uality: a emission-control case, with the available emission budget estimated in terms of the blended principle of both inertia and equality.

Equal **Equal**ity: a emission-control case, with China's cumulative available emission space allocated and determined by the equality principle, given the 2C warming-limit goal.

Mincost **Min**imizing **Cost** Distribution: a emission-control case, with the cumulative available emission budget allocated by the principle of minimizing distribution of relative mitigation costs.

The analyses that assess the energy (oil) intensity and energy (oil) expenditures support the finding that implementation of emission control policies yields the prominent co-benefits of energy safety, regardless of whether looking at the short-, medium- or long-term. As observed from the perspective of per capita energy (oil) consumption, the introduction of emission budgets promotes the decrease in both per capita energy and oil consumption. These outcomes translate to an increase in the energy system security to a large extent. However, this effect is sensitive to the time scale of climate policies when compared to the long-term, the short- and medium-term influences of the climate policies on per capita energy and oil consumption seem more remarkable. For the metric of energy diversity, the co-benefits of energy safety that result from emission budgets are also closely related to the considered time scales. Specifically, the implementation of emission control policies significantly increases China's energy diversity in the short- and medium-term before 2050. Afterward, energy diversity will decrease until it is lower than the BAU level, at which point, the energy system may become more vulnerable than in the no emission budget cases (Figure. 1).

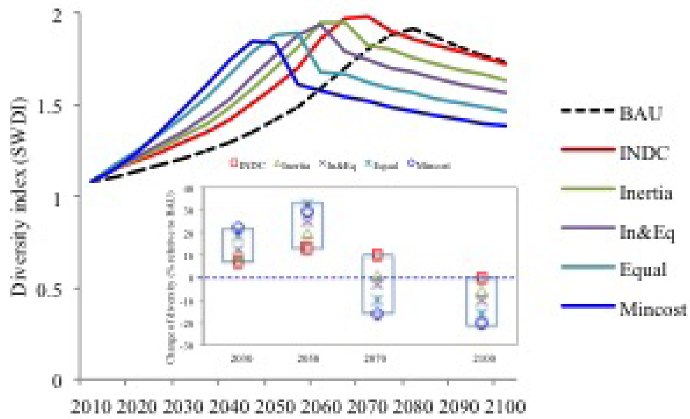

Figure 1. Changes of SWDI-based energy system diversity across various policy scenarios

Note: the embedded subfigure provides the relative changes of SWDI (relative to BAU)

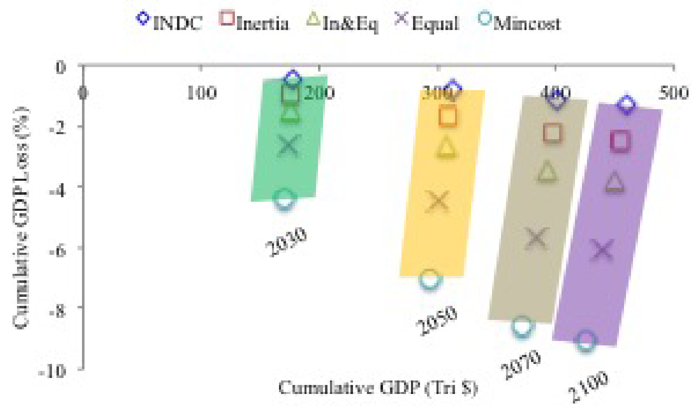

Figure 2. Distribution of cumulative policy costs given different emission budgets (with a 5% discount rate)

Consequently, there is a unidirectional consistency between China's climate policies and energy security; in effect, climate policies in China contribute to avoiding potential climate damages, and bring the numerous co-benefits of energy security, particularly in the short- and medium-term. This finding provides new reasonable support for introducing climate policies at the national level. Further, the macroeconomic costs required to reach China's committed carbon-peaking target might be far lower than the costs required fulfilling the emission budgets under the global 2-degree warming rise threshold (Figure 2), which implies that the economics of climate policy is expected to significantly improve, if the co-benefits of energy security are considered.

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