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Bridging transition pathway with institutions: a theoretical framework of China's climate governance toward carbon neutrality

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Abstract

Non-technical Summary. China formally pledged to peak its carbon emissions within 10 years and achieve carbon neutrality within 30 years thereafter. Considering the numerous challenges and difficulties ahead, it is essential for China to strengthen the building of climate governance systems toward carbon neutrality. This paper examines the interactions between elements of China's climate governance system, and develops a theoretical framework for China's climate governance toward carbon neutrality, with a view to providing more comprehensive information for decision-making.

Technical Summary. China's high ambitions to peak carbon emissions by 2030 and to achieve carbon neutrality by 2060 make climate governance an urgent issue. Against this background, this paper develops a TAM ('Target, Actor, Mechanism') theoretical framework for China's climate governance toward carbon neutrality, intending to provide information for decision-making. This framework, centering on governance actors, is based on two key assumptions: First, the stance of each actor toward a climate action depends on the impact of this action on the actor's objectives and the weight of these objectives to this actor; Second, the most feasible governance mechanism is the solution that can best satisfy actors' objective with the greatest decision-making influence. Applying this framework in case studies involves three major steps: (1) Identifying China's climate governance actions according to transition pathways toward carbon neutrality; (2) Assessing the effects of climate actions on the objective of relevant actors; (3) Obtaining feasible governance mechanisms based on historical institutionalism analysis. By linking different climate governance research methodologies, this theoretical framework can provide decision-makers with more comprehensive information on climate governance.

Social media summary. Integrating quantitative models with institutionalism can bridge the gap between policy formulation and implementation.

1. Introduction

Following the Paris Agreement, a growing number of countries have adopted carbon neutrality as a long-term climate goal. By November 2023, around 145 countries had already or were preparing to set their net-zero or carbon neutrality targets (NZT, 2024). In 2020, China also formally announced its 'Dual Carbon' targets to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. Compared to other countries, China's current stage of economic development, industrial structure, and energy supply and use patterns make it particularly difficult to achieve carbon neutrality (Chen et al., 2022; Tan et al., 2022a). It suggests that China should strengthen its climate governance capacity, and develop a systematic approach to carbon neutrality.

Against this background, it is urgent to develop a theoretical framework to analyze the governance issues, providing insights for the decision-making of climate governance toward carbon neutrality. The building of this theoretical framework should take into account two aspects. First, how to coordinate governance practices and future target-oriented governance needs. Since climate governance is a part of China's national governance system, its trajectory, choices, and consequences are largely determined by China's institutional and political structure (Teng & Wang, 2021). Consequently, research on climate governance should consider the internal logic and mechanism of action of China's actual practices. Second, climate governance is the 'art of the possible' rather than the 'calculation of the optimal' (Buck, 2018; Geels et al., 2017). Economists usually believe that market-based policies, such as carbon pricing, are the most cost-effective instruments to address collective climate actions. However, previous governance experience demonstrates that green industry policies aimed at stimulating the development of low-carbon technologies are dominant (Pahle et al., 2018). Especially, when it comes to carbon neutrality, profound socio-economic transitions will create 'winners' and 'losers'. As a result, climate governance is more about problem-solving through adaptive coordination rather than direct control (Wise et al., 2014). It means that the theoretical framework should include a representation of the decision-making process that can reflect the interactions between different actors.

This paper has contributed by developing a theoretical framework for China's climate governance toward carbon neutrality. The theoretical framework bridges transition pathways with historical institutionalism analysis, thus providing more comprehensive information for decision making and obtaining a politically feasible governance solution. The paper proceeds as follows. Section 2 briefly reviews the literature on climate governance from the perspective of two research paradigms. Section 3 analyzes the evolution of China's climate governance, and elaborates the interactions between the three governance elements. Section 4 develops the theoretical framework and demonstrates how to apply it to case studies. Section 5 concludes.

2. Literature review

Research on climate governance can be generally divided into two paradigms. The first research paradigm focuses on establishing quantitative relationships between specific climate governance mechanisms and their governance performance. Extensive studies have used quantitative models to assess the impact of broader climate policies on climate governance, such as climate legislation (Averchenkova et al., 2021; Eskander & Fankhauser, 2020) and renewable energy subsidies (Ma et al., 2021). The Integrated Assessment Models (IAMs) are widely used in long-term low-carbon transition planning (Hof et al., 2020). These models are driven by the interactions between the carbon pricing and the technological configuration of energy-related societal sectors. Having defined a specific endpoint in an ideal future state (such as net-zero emissions), they can back-cast to determine the technology and investment portfolios required to achieve the target (Farmer et al., 2015; Hollnaicher, 2022; Nilsson et al., 2011). The insights of this paradigm for governance decision-making lie in the ability to systematically explore low-carbon transition pathways under different scenarios, and to assess the consequences of different choices, and the trade-offs they entail.

The second research paradigm revolves primarily around specific climate governance practices. Some studies focus on analyzing the general architecture of climate governance, and comprehensively reviewing the current state of governance (Flachsland & Levi, 2021; Wang et al., 2018). In order to better inform future decision-making, scholars have developed several theoretical frameworks aimed at understanding the mechanism of action of climate governance. Among these, the socio-technical transition theory is a commonly used analytical perspective that starts from technological change (Edmondson et al., 2019; Wu et al., 2021).

Meanwhile, historical institutionalism is another important analytical perspective as a major strand of the new institutionalism (Lockwood et al., 2016). It differs from rational choice institutionalism and sociological institutionalism, which originated in political science (Andrews-Speed, 2016). The political nature of historical institutionalism implies the need to analyze the full range of actors involved in climate governance and the relationships between them. In particular, it focuses on the struggles between interest groups and actors during the policy processes (Roberts & Frank, 2019). Some scholars have emphasized the importance of creating new actor networks, forming advocacy coalitions, and raising the political priority of addressing climate change across different administrative domains, in order to create a positive impact on long-term climate policy dynamics (Gomel & Rogge, 2020; Lindberg & Kammermann, 2021; Meckling et al., 2015). Other scholars have argued for policy feedback theory, which suggests that climate policy, in the process of being formulated, shall not only consider the substantive effects of policy implementation (such as reducing greenhouse gas emissions), but also encourage positive feedback and avoid or mitigate negative feedback (Jacobs & Weaver, 2015; Pierson, 1993). The self-reinforcing policy feedback typically takes the form of lowering economic costs, reducing free-riding behavior, and enhancing governance capabilities (Furumo & Lambin, 2021; Meckling et al., 2017; Smith, 2020).

The climate governance toward carbon neutrality in China is a complex system involving multiple targets, actors, and governance mechanisms. Accordingly, decision-makers need to acquire more information before making decisions (Horcea-Milcu et al., 2024). Given that different research paradigms tend to emphasize different features of climate governance and develop different representations of the governance process (Cherp et al., 2018; Rosenbloom, 2017), these paradigms have complementary strengths and weaknesses (Hof et al., 2020). Subsequently, some scholars have suggested that linking these paradigms may help provide more information for governance decision-making (Turnheim et al., 2015). Guided by this insight, this paper develops a theoretical framework for climate governance which links different methodologies. By integrating quantitative models and historical institutionalism analysis, the framework can characterize the targets-driven behaviors of actors, and reflect the influence of actors on the decision-making process. Accordingly, compared to existing research, which tends to focus only on the links between different methodologies in terms of the choice of key parameters and assumptions, this paper focuses not only on what policy design entails, but also on how to balance the interests of different actors through institutional arrangements, thereby narrowing the gap between policy formulation and implementation.

3. Interactions between elements of China's climate governance

The theoretical framework has been developed in two steps. The first step is to clarify what governance elements are included in this framework. Referring to Xue and Yu (2015), we developed the theoretical framework for China's climate governance toward carbon neutrality around three central elements, namely (i) climate governance targets, (ii) the relevant actors, and (iii) the governance mechanisms, which primarily denote the relevant institutions and policies to address climate change.

The second step is to analyze how the individual elements interact with each other to address climate change. Climate change is seen as a collective action problem (Nordhaus, 2015). Therefore, according to solutions to collective action problem put forward by Young (2013), climate governance can be accomplished through two processes: the first is to translate governance targets into climate actions; and the second is to increase the motivation of relevant actors to engage in climate actions through governance mechanisms. In order to align the framework with China's reality, this section aims to clarify the interactions between various elements of these two governance processes by summarizing China's past practices in climate governance.

3.1 Interactions between elements in the process of decomposing governance targets

The process of decomposing governance targets in China involves two modes. The first is to directly allocate climate targets to actors, which is realized through China's 'target responsibility system' (TRS). In 2007, the *Outline of the 11th Five-Year Plan (FYP) for National Economic and Social Development* established a TRS centered on energy intensity. Subsequently, the TRS also included the total energy consumption and carbon intensity. Under the TRS, the central government sets the overall national climate target, and allocates it to provinces. Each province then distributes its target to municipalities until all levels of government are assigned a target (Cheng et al., 2022).

The second is to translate governance targets into climate actions, and guide and incentivize the participation of a wider range of actors. In 2011, the Outline of 12th FYP formally included targets and priorities for addressing climate change. On this basis, the State Council took the lead in releasing the *Plan for Controlling Greenhouse Gas Emissions during the 12th FYP Period*. Subsequently, several ministries collaborated in formulating sector-specific or technology-specific FYPs according to the climate change priorities set out in the Outline of 12th FYP. Currently, China's carbon abatement actions mainly involve four aspects: improving the energy efficiency of energy-intensive industries, increasing the share of low-carbon industries to realize the transformation of the economic structure, increasing the share of non-fossil energy in the primary energy mix, and increasing carbon sequestration through afforestation.

3.2 Interactions between elements in the process of guiding the participation of various actors

China guides and incentivizes the participation of various actors in climate actions mainly through the formulation and implementation of a set of climate policies. Climate policies can be divided into three types, i.e. regulation instruments, economic instruments, and information instruments (Rogge & Reichardt, 2016). Regulation instruments can directly curb emissions from companies in key industries. For example, China has continuously improved energy efficiency standards for coal-fired power plants.

Compared with regulation instruments, economic instruments are more commonly used in China (Tan et al., 2022a, 2022b). For energy-intensive and high-emitting enterprises that take responsibility for reducing emissions, there will be additional costs associated with reducing product output, purchasing specialized pollution control equipment, or adjusting the production process. To incentivize these actors, China tends to introduce financial support and subsidy policies. In addition, in order to upgrade industrial structure and develop emerging industries, China has also implemented economic policies, such as tax relief, for low-carbon technology and service providers. In addition, the scope of information instruments is relatively broad, encompassing aspects such as education, social advocacy, and voluntary mechanisms, making it challenging to provide a unified characterization of their function mechanisms. Consequently, the theoretical framework to be constructed in the following section will primarily focus on regulation instruments and economic instruments.

4. The theoretical framework for China's climate governance toward carbon neutrality

Based on the identified interactions between elements, this section develops a theoretical framework for China's climate governance toward carbon neutrality. For the process of decomposing and achieving governance targets, the theoretical framework is designed with a module of decomposing the carbon neutrality target, which helps to identify the key climate actions in various fields for achieving carbon neutrality. For the process of guiding and incentivizing actors to participate in climate actions, the theoretical framework includes two modules. The first module is to verify the effectiveness of governance mechanisms in guiding and incentivizing actors' motivation by evaluating the effects of a certain climate action or governance mechanism on actors' targets, while the second module is to analyze the distributional effects among actors for the purpose of designing a feasible governance mechanism. Throughout the paper, we use the acronym TAM ('Target, Actor, Mechanism') when referring to this framework.

4.1 Module 1: decomposing the carbon neutrality target and identifying climate actions

In China's climate governance practice, key climate actions to meet climate targets are usually determined by drawing lessons from previous FYPs and collecting information from a series of consultations with experts and subnational governments (IEA, 2021). Given that the actions are all target-oriented, the framework needs to explore possible future scenarios. Consequently, this paper attempts to use the low-carbon pathways stimulated by the IAMs adopted by several governments to assess climate governance around the world (Farmer et al., 2015).

With advances in modeling techniques, current IAMs can characterize different climate change response systems and project their low-carbon transition pathways. The output variables include technology and funding portfolio, etc. Therefore, this framework translates the output variables into a set of climate actions $\boldsymbol{P}$ [p_1, …, p_h] for China to realize the carbon neutrality target. For a given action p, the government can track and evaluate the progress of its implementation by setting several sub-targets, denoted by $\boldsymbol{O^p}$ [O_1^p, …, O_y^p]. For example, China has set installed capacity targets of different renewable energy sources in FYPs for renewable energy since 2007.

4.2 Module 2: selecting actor's objectives and assessing the effects

After obtaining the action set $\boldsymbol{P}$, the second module will focus on analyzing the participation process of various actors, including how to characterize actors' motivation to engage in climate actions, and the impact of different institutions and policies on actors' motivation. In China, the government, businesses, the public, research institutions, think tanks, and NGOs, all play a role in climate actions within climate governance system (Wang et al., 2018; Zhang, 2024). For each actor i involved in climate action p, it is assumed that its motivation is determined by the effects of action p on its objectives. For example, objectives with greater influence on the government's decisions mainly include

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investment and employment. For companies, profit may be the main concern.

The set of actors involved in climate action p is denoted by $\boldsymbol{A}$ $[1, \ldots, a]$, and the set of objective of actor i is denoted by $\boldsymbol{w_i}$. The concatenation of $\boldsymbol{w_i}$ must satisfy the condition that it can fully cover the sub-target set $\boldsymbol{O^p}$, as shown in Equation 2–1:

$$O^p \subseteq \bigcup_{i=1}^{a} w_i \tag{2-1}$$

On this basis, referring to Jakob et al. (2020), the motivation of actor i for climate action p depends on the impact of p on objective k and the relative weight of objective k for actor i, as shown in Equation 2–2:

$$G_i(p) = \sum_{k=1}^{b_i} \alpha_{i,k} \cdot F_{i,k}(p) \tag{2-2}$$

$G_i(p)$ is the total target function that measures the motivation of actor i toward climate action p. b_i denotes the number of objectives of actor i. The weight $\alpha_{i,k}$ indicates the importance of objective k to actor i. If objective k is not important to actor i, $\alpha_{i,k}$ will take a small value; if objective k is among the core interests of actor i, $\alpha_{i,k}$ will take a relatively large value among the objectives in $\boldsymbol{w_i}$. At the same time, the total objective function G is also affected by the specific effects of p on objective k, denoted by $F_k(p)$.

Based on the characterization of actors' motivation in Equation 2–2, the mechanism of action of governance mechanism is expressed as increasing actors' motivation toward climate action p through the implementation of institution C and policy Q. In terms of institutional arrangements, the theoretical framework mainly considers the TRS (C_t), as shown in Equation 2–3:

$$G_i(p|C_t) = \sum_{k=1}^{b_i} \alpha_{i,k}(C_t) \cdot F_{i,k}(p) \tag{2-3}$$

$G_i(p|C_t)$ represents the motivation of actor i affected by institution C_t. C_t can increase the weight $\alpha_{i,k}$ by assigning the objective k to actor i (e.g. energy intensity and carbon intensity targets) and tracking target performance through the Statistics Indicators, Monitoring, and Examination (SME) system. In the TMA framework, the mechanism of action is expressed by setting the weight $\alpha_{i,k}$ as a function of C_t. The institutional arrangements can not only directly adjust the weight of the climate objective, but also indirectly enhance the relative weight of the climate objective by changing the weight of other objectives, so as to increase actors' motivation toward climate actions.

As for climate policies, different policy instruments can impose various effects on the total target function $G_i(p)$. The mechanism of action of regulation policy instrument (denoted by Q_o) can be described as requiring actor i to take the climate action, through which specific climate targets can be met, as shown in Equation 2–4.

$$G_i(p|Q_o) = \sum_{k=1}^{b_i} \alpha_{i,k} \cdot F_{i,k}(Q_o) \tag{2-4}$$

As the same time, the economic policy instrument (denoted by Q_e) occupies a dominant position in China's current climate policy mix. In the TMA framework, its mechanism of action is expressed as increasing the motivation of actor i toward climate action p by affecting $F_{i,k}$, i.e. increasing the positive effects of objective k, as shown in Equation 2–5:

$$G_i(p|Q_e) = \sum_{k=1}^{b_i} \alpha_{i,k} \cdot F_{i,k}(p|Q_e) \tag{2-5}$$

4.3 Module 3: Designing the governance mechanism

The implementation of institution C or policy Q may impose different impacts on different actors, leading to distributional effects between them. In particular, ambitious climate actions or stringent climate policies may entail losses for certain actors, thus hindering the implementation of policies. Therefore, the finalization and introduction of policies often needs to go through an interactive process where the distributional effects between different actors will be coordinated. In response to this process, it is hypothesized that the most feasible governance mechanism is the solution that can best satisfy actors' objectives with strong policymaking influence. The coordination process is then characterized through the following two equations:

$$J(p) = \sum_{i=1}^{a} \delta_i(C) \cdot G_i(p|Q, C) \tag{2-6}$$

$$Z_p^*(C^*, Q^*) = \max_{C,Q} J(p) \tag{2-7}$$

$J(p)$ denotes the political support for institution C and policy Q aimed at promoting action p, reflecting the political feasibility of the governance mechanism. δ_i reflects actors' decision-making influence on action p. The finally obtained governance mechanism Z^*_p (C^*, Q^*) is the option receiving the greatest political support and thus the most feasible one. According to Equation 2–6, there are two ways to obtain Z^*_p (C^*, Q^*). The first is to change δ_i. The second is to reduce negative impacts of p or the original policy Q on actors that have the most pronounced influence on governance decision-making.

4.3 Application of the theoretical framework

By integrating the above three modules, we have obtained the theoretical framework, as shown in Figure 1. In general, after translating China's carbon neutrality target into climate actions $\boldsymbol{P}$ $[p^1, \ldots, p^z]$, the TAM framework takes each specific action p as the unit of analysis, intending to find out the governance mechanism Z^*_p that can effectively promote action p.

The obtaining of governance mechanism Z^*_p can be summarized in Equation 2–8. The target function shows that, compared to traditional governance research that emphasizes obtaining the solution with the least cost or the greatest benefit, the TAM framework developed in this paper pays more attention to the support of actors, in order to find out a more feasible solution. The acquisition of this solution takes into account the objective effects F_i (p), the weight of objectives α_i, and the influence on the decision-making process δ_i. At the same time, several constraints have to be taken into account. In particular, the set of

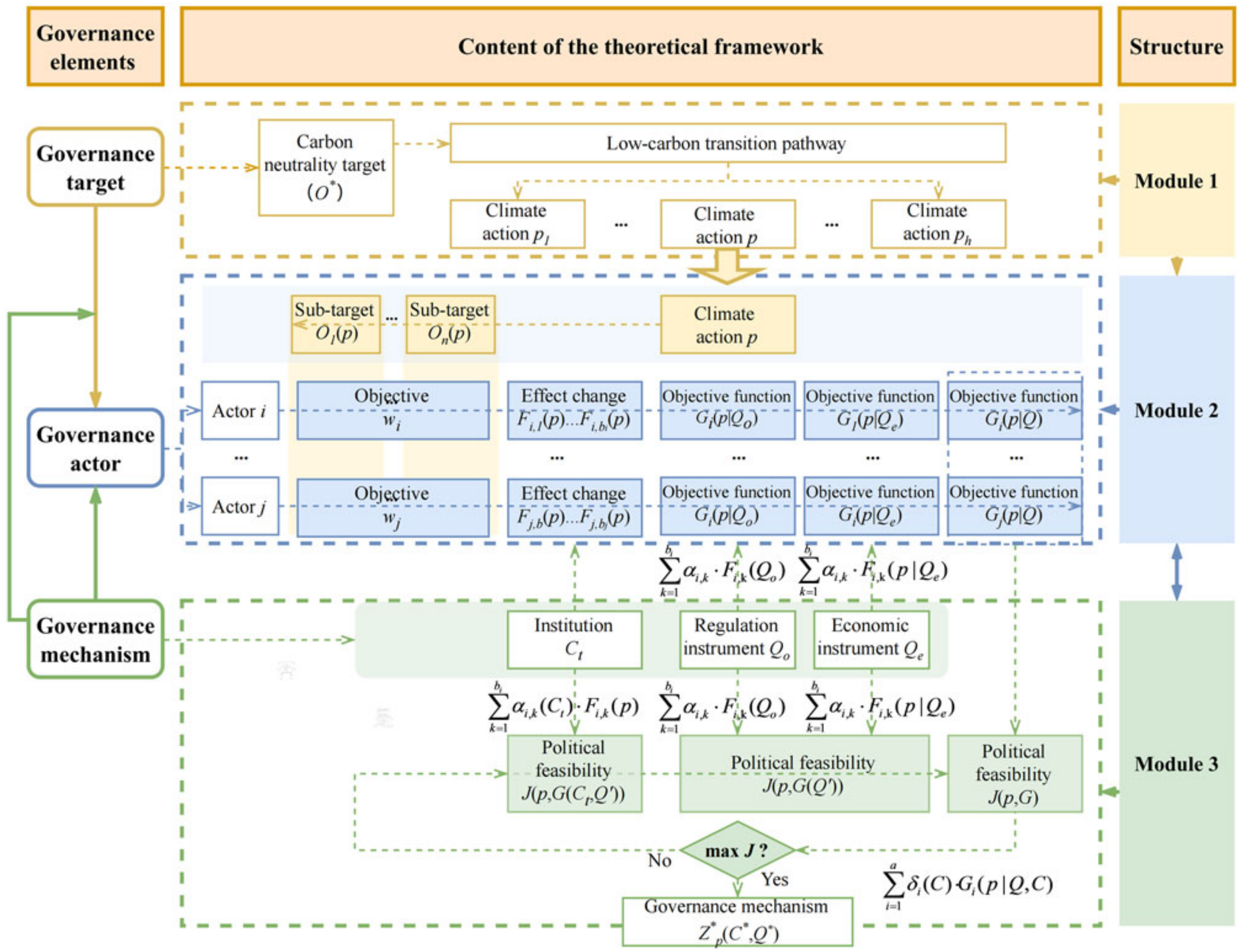

Figure 1. Graphical representation of the TAM framework.

objectives $\boldsymbol{W}$ of all actors involved in action p must fully cover the set of sub-targets $\boldsymbol{O^p}$. Institution C mainly includes the TRS C_t, and policy includes regulation instruments Q_o and economic instruments Q_e. In fact, these constraints represent to some extent the characteristics of each element in China's climate governance system.

$$
\begin{aligned}
&\max J(C, Q) = \sum_{i=1}^{a} \delta_i(C) \cdot G_i\Big(\sum_{k=1}^{b_i} \alpha_{i,k}(C) \cdot F_{i,k}(p|Q)\Big) \\
&s.t.\ C \in C_t \qquad\qquad (2\text{-}8) \\
&Q \in (Q_o, Q_e) \\
&O^p \subseteq W
\end{aligned}
$$

when applying the theoretical framework to case studies, the three modules correspond to three steps. Step 1 is to translate the transition pathways of IAMs into climate actions. As differences between IAMs, especially in their solution methods, parameter settings, and scenario design, often lead to inconsistent conclusions on key issues such as technology choices and socio-economic impacts (Kong et al., 2023), the theoretical framework considers the use of multi-model comparison analysis to obtain more robust results.

Step 2 involves selecting actors' main objectives and assessing the effects of the objectives, which mainly relies on quantitative modeling. The commonly used methods include the system dynamics model, multiple-actor evolutionary game model, and other quantitative models that can represent the interactions between various actors.

Compared with regulation instruments and economic instruments characterized by quantitative modeling, the weight of objectives α, and the influence on decision-making process δ are usually characterized as relatively 'large' and 'small', which are difficult to assign precise values, and thus are not suitable for quantitative modeling. As a result, Step 3, referring to Lockwood et al. (2016) and Andrews-Speed (2016), is to introduce historical institutionalism to analyze the decision-making process. It focuses on how institutions shape the distribution of power and power structures, which is compatible with the hypotheses of maximum political support in this theoretical framework. To be specific, Step 3 begins with an analysis of institutions involved in climate action p to clarify the power structure between the actors, which can help understand the weight of objectives α and the influence on the decision-making process δ. Then, the policy feedback theory under historical institutionalism is applied to analyze how to

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Table 1. Climate governance from different perspectives represented in the ATM framework

Perspectives considered	Representation in framework	
IAM, Multi-model comparison analysis	Climate actions under the carbon neutrality target	$\boldsymbol{P}\ [p^1, \ldots, p^h]$ $\boldsymbol{O^P}\ [O_1^p, \ldots, O_c^p]$
Actors' objective	Objective list of various actors	$\boldsymbol{w_i}\ [1, \ldots, b_i]$
Quantitative modeling	Effects on actors' objectives	$F_{i,1}(p), \ldots, F_{i,bi}(p)$
Historical institutionalism	Institution and power structure	$\alpha_{i,1}, \ldots, \alpha_{i,bi}$ $\delta_{i,1}, \ldots, \delta_{i,bi}$
Policy feedback	Adaptive coordination and decision-making process	J

ultimately obtain a feasible governance mechanism by creating positive policy feedback or mitigating negative policy feedback. In conclusion, the TAM framework is able to accommodate different perspectives on climate governance, as summarized in Table 1.

5. Discussion and conclusions

In terms of effective climate governance toward carbon neutrality, there is still a lack of methodologies that can simultaneously address both current governance practices and future target-oriented governance needs. In this regard, this paper develops a theoretical framework for China's climate governance to fill this gap.

In terms of research methodology, this paper provides a general theoretical framework for studying China's climate governance toward carbon neutrality. It is based on three central elements, namely governance targets, actors and mechanisms. With regard to applying this theoretical framework to climate governance research, this paper allows for the flexibility of combining different theories, and using outputs from one approach to inform analyses in another approach, thus providing additional information for decision making. As for informing governance decisions, the value of the theoretical framework developed in this paper lies in its ability to provide a politically feasible governance mechanism. In particular, by identifying in advance the sources of political resistance to the implementation of these policies from influential stakeholders, it can help reduce the obstacles through policy feedback, which is critical for China to meet its 'Dual Carbon' targets on schedule.

For future research, the ideas embodied in the theoretical framework can also be used for comparative studies of climate governance in different countries. Existing research tends to focus on institutional and political contexts and the resulting differences in the governance process. By taking the governance actor as a key leverage point, this theoretical framework can help to understand why the same climate policies are effectively implemented in some countries, but fail to deliver the expected performance in others, which has received less attention in existing literature (Schmidt & Huenteler, 2016).

Furthermore, most studies on low-carbon transition based on IAMs remain somewhat disconnected from decision-making. One reason is that the backcasting is primarily based on projections of future costs and performance of different technologies. As a result, it may reflect quantifiable interrelationships between technology, economy, and environment, but may overlook the institutional drivers of the low-carbon transition (Nilsson et al., 2011). Some scholars have called for the inclusion of political and institutional variables in IAMs. From this perspective, the representation of the two variables in this theoretical framework—the weight of targets and the influence of actors on decision-making—can provide some new perspectives. It is hoped that more in-depth research on these two variables will provide a solid empirical basis for their representation in IAMs.

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