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Understanding the Evolving International Collaborative Governance for Transboundary Air Pollution in Northeast Asia: An Institutional Collective Action Perspective

Jianzheng Liu[a,b,c], Wang Zhang[a], Peiling Zhou[d], Jiawei Li[e], Tian Feng[f] and Hongyan Zhao[g]

[a]Xiamen University; [b]Fujian Key Laboratory of Sensing and Computing for Smart Cities; [c]Xiamen Key Laboratory of Integrated Application of Intelligent Technology for Architectural Heritage Protection; [d]Harbin Institute of Technology (Shenzhen); [e]Chinese Academy of Sciences; [f]Ningbo University; [g]Beijing Normal University

ABSTRACT

This article draws on the institutional collective action (ICA) framework to summarize the evolving collaborative mechanisms for addressing transboundary air pollution developed by countries in Northeast Asia (NEA) over the past three decades and to explain why NEA countries selected these mechanisms over time. We find that the three decades of collaboration can be divided into three stages with three interconnected and progressive goals: information exchange, joint research and technical cooperation, and action plans. The choice of mechanisms by NEA countries at different stages depends on the collaboration risks at that stage and the costs of the mechanisms under consideration. Because of the increasing collaboration risk, participating countries tend to use informal embedded mechanisms in the first stage of information exchange, then the formal contractual mechanisms at the second stage of joint research, and the most formalized authority mechanisms at the third stage of action plans. However, if the costs of the authority mechanisms are too high, participating countries may fall back on the contractual mechanisms. This article extends the ICA framework beyond local governments to transnational environmental collaborations involving national state actors, identifies three collaboration risk sources, and reveals how the mechanism choice shifts over time in this context.

KEYWORDS

Collaborative environmental governance; environmental cooperation; institutional collective action framework; Northeast Asia; transboundary air pollution

Introduction

Air pollution has become an increasingly international issue due to its transboundary nature and cross-border detrimental effects on human and environmental health (Liu et al., 2025). This is particularly true in Northeast Asia (NEA), as China, South Korea, and Japan have been suffering from

CONTACT Peiling Zhou lindaplzhou@gmail.com Harbin Institute of Technology, Shenzhen, 518055, Shenzhen, China.

severe transboundary air pollution (TAP)[1] since the 1980s. The TAP leads to adverse health impacts on residents, and has consequently sparked substantial public concern in NEA.

Apparently, a collective action problem emerges in NEA as no single country can independently address this transboundary challenge. While the mitigation of TAP would yield benefits for all participating countries, some countries may exhibit reduced motivation to take collective action. This reluctance stems from the fact that the costs associated with the pollution control are disproportionately borne by upwind countries. In order to address TAP that spills across jurisdictional boundaries, NEA countries have established various collaborative government arrangements over the past three decades (1988–2019). However, these arrangements are poorly coordinated and weakly regulated (Lee & Paik, 2020; Yarime & Li, 2018). To date, no concrete regional regulatory mechanism with binding power for addressing TAP is being developed in NEA (Choi, 2019; Lee, 2001), and international environmental collaboration in this region continues to be conducted through non-binding agreements (Yoon, 2007). This persistent reliance on soft-law approaches stands in contrast to the more institutionalized and legally binding frameworks adopted in other regions, such as Europe and North America (Byrne, 2017; Hurley & Lee, 2021). This raises important questions about the choices made by NEA countries: Why did NEA countries choose the non-binding agreements over the past three decades? What factors have hindered the development of legally binding collaborative mechanisms with mandates to tackle TAP more effectively?

This study aims to answer the research questions above by focusing on two research objectives. The first objective is to describe and summarize the collaborative mechanisms developed by NEA countries to address TAP over the past three decades. The second objective is to explain why NEA countries selected the non-binding collaborative mechanisms over time instead of other legally-binding mechanisms. To achieve the research objectives, this study draws on the institutional collective action (ICA) framework to understand the evolving collaborative mechanisms on TAP in NEA. As global warming and drought unleash more forest fires, the TAP has become a compelling and highly visible policy issue. The answers to the questions on TAP governance not only help us better understand the historical development, current status, and the future prospects of the international collaborative governance on TAP in NEA, but also advance a theoretical understanding of how collaborative mechanisms evolve in the context of transnational collaboration for transboundary environmental issues.

The rest of the paper is structured as follows: the second section reviews previous studies on collaborations on TAP in NEA and the evolution of collaborative governance, and introduces the ICA framework. The third

section describes the data collection and analysis method. The fourth section summarizes the evolving collaborative mechanisms for addressing TAP in NEA, followed by an analysis of the underlying logic behind the evolving mechanisms. The discussion and conclusion section concludes the paper with a brief summary of the findings, theoretical and practical implications, and suggestions for future research.

Literature review and theoretical framework

Literature review

Challenges of international collaborative governance for TAP in NEA

Since the late 1990s, several studies have been conducted to summarize collaborative mechanisms and explain challenges and barriers hindering deeper and closer international collaboration for transboundary environmental issues in NEA (Lee, 2001; Takahashi, 2001). These studies can be categorized into three research streams that used different perspectives. The first research stream adopted an economic perspective to investigate regional environmental cooperation in NEA (Jho & Lee, 2009; Kim, 2007; Yoon, 2007). This research stream contended that the significant disparities in economic development and varying economic interests among NEA countries made it challenging for national state actors to maintain appropriate levels of interest in shared environmental issues and establish unified goals for cooperation. The second research stream analyzed international environmental collaboration from an international relations perspective (Kim, 2014; Yoshimatsu, 2010a, 2010b). Scholars argued that the rivalry between China, South Korea, and Japan led to a strong insistence on state sovereignty (Kim, 2014), and hindered the NEA region in building overarching regional institutional arrangements (Yoshimatsu, 2010a). The third research stream focused on expert communities in NEA countries (Akimoto et al., 2022; Shapiro & Yarime, 2021; Yarime & Li, 2018). This stream suggested that the fragmented epistemic communities in NEA countries made it difficult for NEA countries to reach a consistent scientific understanding of TAP in NEA. This has led to recurring debates on the sources and attribution of transboundary pollution, which have caused conflicts among the public, media, and governments in NEA countries during the process of establishing effective environmental cooperation.

These studies have shed light on obstacles to effective international environmental collaboration from economic, international relations, and epistemic community perspectives. However, they provided a fragmented view of the various factors influencing environmental collaboration in NEA. There is a need for an integrated understanding of the sources of obstacles to effective international environmental collaboration and how these sources contribute to collaboration failure. Scholars have noted the

fragmented view and have recently attempted to gain a more comprehensive understanding of such obstacles (Lee & Paik, 2020). However, these studies did not fully explain why NEA countries chose or rejected certain collaborative mechanisms. Moreover, previous studies only focused on specific time periods and examined a limited number of collaborative arrangements (Kim, 2014; Lee & Paik, 2020; Takahashi, 2001). As a result, existing studies have incorrectly treated changing collaborative mechanisms as separate entities with no connection to one another. No study has ever offered an updated and comprehensive summary and explanation of the evolving collaborative mechanisms for addressing TAP in NEA over the past three decades.

Evolution of collaborative governance

While there is extensive literature on collaborative governance (Christensen, 2024), studies focusing on the evolution of collaborative governance remains limited (Bell & Olivier, 2022). Most studies have concentrated on the dynamics of the features of collaborative processes rather than the evolution of the collaborative mechanisms. These studies have investigated various aspects of the collaborative processes, including the change of collaboration ties among organizations from disaster preparedness to disaster response (Kapucu & Hu, 2016), the change of the internal operation and communication over time (Heikkila & Gerlak, 2016), the dynamics of collaborative outcomes (Bell & Olivier, 2022), and the changes of obstacles that a collaborative network faces as it evolves through different stages of its lifecycle such as activation, institutionalization, and stability, decline, and change (Imperial et al., 2016; Ulibarri et al., 2020). These stages are conceptualized through a lifecycle model, which provides a useful model for understanding developmental trajectories of collaboration. The lifecycle model posits that collaboration usually moves through the following stages: activation, institutionalization, and stability, decline, and change. In the activation stage, participants are "building relationships rather than accomplishing tasks" to figure out the intentions and goals of other participants (Imperial et al., 2016, p. 137). The main theme of activation stage is to find common ground (Bell & Olivier, 2022). At the stage of institutionalization, participants aim to solidify the network and make the collaboration more reliable for new demanding tasks. This is usually done through "institutionalizing" the collaboration by signing formal collaboration agreements (Imperial et al., 2016). The stages in the lifecycle model of collaborative processes provide a foundation for the evolution of collaborative mechanisms in this study. Advancements in collaboration processes are often accompanied by corresponding developments in collaborative mechanisms. But there are distinctions between the evolution of collaborative processes and the evolution of collaborative mechanisms. The evolution

of collaborative processes emphasizes the dynamic changes in collaborative behaviors and relationships over time, focusing on how actors interact and how these interactions drive the development of collaboration. The evolution of collaborative mechanisms, on the other hand, focuses on the changes in the institutional frameworks that underpin these behaviors and relationships, analyzing how these frameworks transition from informal to formal arrangements.

Only a few studies have examined the evolution of collaborative mechanisms. Chow et al. (2023) conducted a case study on collaborative governance in combating air pollution from shipping in the Guangdong–Hong Kong–Macao Greater Bay Area. They found that scientific research could reduce uncertainties and facilitate the transition process of the collaborative governance framework from the operational level to organizational level and then to policy level during the policy development process. Utilizing empirical data in the Orlando metropolitan area, Hawkins et al. (2016) found that collaborative regional institutions could help turn the informal network relationships between local governments into a formal agreement. While these two studies offered valuable empirical insights, they only highlighted the influence of scientific research and regional institutions on the evolution of collaborative mechanisms. They have not provided a comprehensive account of the diverse factors that drive the mechanism changes.

Woods and Bowman (2018) provided a way of thinking about the various factors behind the changes of collaborative mechanisms. Drawing on the ICA framework, the study examined the changes of collaborative agreements concerning juveniles among the states in the United States, and found that the evolution of the collaborative mechanisms depends on how the state governments tradeoff between the transaction costs and the potential policy gains (Woods & Bowman, 2018). Although the study only focused on a limited number of collaborative mechanism types at certain collaboration stages, it demonstrates the ICA framework's utility as a theoretical approach to understand the dynamics of collaborative mechanisms. Therefore, this study draws on the ICA framework to provide a more nuanced understanding of the interplay of factors that shape the evolution of the collaborative mechanisms in NEA.

ICA framework

The ICA framework is a theoretical approach developed by Richard Feiock and colleagues to examine why actors collaborate and how they utilize different collaborative mechanisms to resolve collective action problems (Feiock, 2007, 2009, 2013, 2016; Feiock & Scholz, 2010; Kim et al., 2022). The development of this theoretical framework has been shaped by theories

of collective action (Ostrom, 1990, 2005), transaction cost theories of organizations (Brown & Potoski, 2005), and network theories of social embeddedness (Axelrod, 1984; Putnam, 1993), etc. The ICA framework is particularly relevant for this study because the governance of TAP is a typical collective action issue which requires collective action by all countries: the air pollution emitted by a country produces negative externalities that spill across jurisdictional boundaries.

The ICA framework provides a meaningful conceptual system for understanding various collaborative mechanisms. It explains why these mechanisms emerge, what risks and transaction costs they entail, and how they can be sustained (Feiock, 2007, 2009, 2013; Kim et al., 2022). First, the ICA framework provides a well-defined taxonomy of collaborative mechanisms, which helps summarize various collaborative mechanisms developed by NEA countries in addressing TAP (achieving the first research objective). The ICA framework refers to these collaborative government arrangements as "integration mechanisms" in which actors use formal or informal rules to overcome barriers to collective actions (Ostrom, 1990). According to the framework, there are generally four types of collaborative mechanisms: network embeddedness, contracts, delegated authority, and imposed authority (Feiock, 2009; Feiock, 2013; Yi et al., 2018). The embeddedness mechanism coordinates actors and enforces agreements among actors through flexible rules and informal networks of relationships. In a contractual mechanism, actors are requested to provide formal consent to enter a contractual relationship by signing agreements. The contractual relationship can bind actors to some degree, but it is voluntary and non-mandatory by nature (Tavares & Feiock, 2018). Therefore, a contractual mechanism usually provides a more formalized mechanism with a formal organizational structure for resolving externalities that concern all parties while preserving the autonomy of the involved actors. Under the mechanism of delegated authority, actors jointly create a regional authority and delegate power to the authority that can take direct action. It requires the integration of activities and functions performed by individual actors into a new organization. The last mechanism is imposed authority, in which a higher-level authority internalizes externality issues by centrally directing and mandating collaborative actions among existing fragmented government units. Unlike other mechanisms, imposed authority is a result of external pressures to end the local unit as an autonomous entity and adopt consolidated solutions (Feiock, 2009).

Second, the concept of collaboration risk in the ICA framework allows us to understand and integrate the various factors influencing environmental collaboration in NEA (achieving the second research objective). Collaboration risk refers to actors' assessment of the likelihood that collective goals will not be achieved (Feiock, 2013; Feiock & Scholz, 2010;

Kim et al., 2022). Collaboration is risky because it can fail in many ways due to different forms of collaboration risks. The collaboration risk manifests itself in three categories: (1) the risk of incoordination in which actors are unable to reconcile mutually beneficial opportunities; (2) the risk of unfair division, where actors have conflicting views about how to share the benefits and burdens; and (3) the risk of defection, where actors may behave opportunistically by concealing information, avoiding responsibilities, or breaking commitments.

The third important conceptual tool provided by the ICA framework is mechanism costs. Mechanism costs are the transaction costs of an integration mechanism, which limit its ability to function and sustain in addressing a collective action problem (Feiock, 2009; Feiock, 2016; Kim et al., 2022). This concept helps explain why actors choose or do not choose certain collaborative mechanisms over time (achieving the second research objective). The ICA framework divides the mechanism costs into autonomy costs and decision costs (Feiock & Scholz, 2010). Autonomy costs refer to transaction costs associated with sacrificing localized autonomy, and decision costs include the costs of searching for information, bargaining, and negotiating. Different collaborative mechanisms face different transaction costs. The costs are highest when formal collaborative arrangements are mandated through government authority, such as the delegated authority mechanisms. Conversely, the costs are lowest when informal collaborative arrangements are based on voluntary relationships and informal networks, such as the embeddedness mechanism (Feiock, 2013).

Although the ICA framework provides a rigorous and theoretically-informed framework for understanding collaborative governance arrangements, limitations remain. First, the ICA framework was developed in studies that examined the collaboration between local governmental units in the Western context. However, experiences from other actors in non-Western contexts should be considered and analyzed to determine whether this theoretical approach can help clarify the phenomenon in contexts with different characteristics. Currently, the ICA framework has been widely used in some policy arenas and countries such as the U.S. (Hansen et al., 2020; Swann & Kim, 2018; Youm & Feiock, 2019), Europe (Tavares & Feiock, 2018; Wittwer et al., 2022), Latin America (Ramírez de la Cruz & Feiock, 2019), and Asia (Chen et al., 2019; 2023; Suo et al., 2023), but existing empirical applications of the ICA framework are predominantly focused on interlocal collaborations between local governments or local non-governmental organizations (Chen & Yi, 2024; Hong & and Jimenez, 2024; Li & Lou, 2024; Pu & Zou, 2025), and rarely examined international collaboration by national state actors in a transnational context. Moreover, the sources of collaboration risk in transnational contexts can be different from those in local settings. Previous research in the literature has analyzed the sources of collaboration

risk in the context of interlocal collaboration on drinking water provision in the U.S. (Hansen et al., 2020). However, no study has systematically identified the unique sources of collaborative risk in the context of transnational environmental collaboration.

Second, most existing ICA studies are cross-sectional and only captured a snapshot of the changing collaborative mechanisms (Kim et al., 2022). Only a few studies examined the evolution of collaborative mechanisms (Chow et al., 2023; Hawkins et al., 2016; Woods & Bowman, 2018). The first two studies only highlighted the influence of scientific research and regional institutions on the evolution of collaborative mechanisms and did not provide a comprehensive account of the diverse factors that drive the mechanism changes (Chow et al., 2023; Hawkins et al., 2016), whereas Woods and Bowman (2018) only focused on a limited number of collaborative mechanism types at certain collaboration stages based on quantitative data without the rich nuance of the dynamic processes of the mechanism evolution. In summary, more research is needed to study how choices of collaborative mechanisms change over time.

Data and method

This research is based on a longitudinal case study of the development of collaborative government arrangements for addressing TAP in NEA over the past three decades. In the case, we observe that the national state actors in NEA have considered and adopted a range of informal and formal collaborative mechanisms over time, such as conferences, joint research programs, environment ministers' meetings, and action plans, which covers most of the integration mechanism types mentioned in the ICA framework. This case thus represents a distinctive opportunity to allow us to examine changes in actors' assessments of collaboration risk and mechanism costs, as well as their choices in selecting collaborative mechanisms.

Data collection

In order to obtain data on actors' assessments, motivations, and behaviors toward collaborations, we searched multiple data sources from China, South Korea, and Japan, including meeting minutes and resolutions from governments and inter-governmental organizations in NEA, policy announcements, presentations, reports, memorandums of understanding, memoirs of high-ranking officials, and newspapers and magazine articles written in English, Chinese, Korean, and Japanese. Secondary data from databases such as Web of Science, China National Knowledge Infrastructure (CNKI), KCI Korean Journal Database, and J-STAGE were also reviewed,

focusing on terms like "transboundary air pollution," "collaboration," "cooperation," and "governance". In total, we analyzed 142 documents, which allow us to trace the development of transnational environmental collaboration on TAP in NEA and therefore provide longitudinal insights unattainable via surveys or interviews alone.

To fill gaps in the document data, interviews were conducted with government officials, university experts, policy analysts, and environmental non-governmental organization (ENGO) managers. These interviews helped clarify areas lacking detail and validate the information from documents. A total of 11 interviewees participated in semi-structured interviews, conducted between June 2020 and January 2024, with an average duration of one hour per interview.

Data analysis

This study primarily uses thematic analysis to identify recurring themes and search for patterns and relationships within the data. A six-phase approach described by Braun and Clarke (2012) is followed to perform the thematic analysis, integrating theory-driven coding (using ICA concepts like collaboration risk and mechanism cost) with inductive methods. Initial codes were developed from documents and interviews, refined through alignment with ICA literature, and organized into thematic frameworks. Two researchers independently coded data, resolving discrepancies through discussion to ensure reliability.

Overview of the collaborative mechanisms for addressing TAP in NEA

This paper conducts a comprehensive survey of the development of collaborative mechanisms for addressing TAP in NEA over the past three decades. Based on the discussions of the process and stages of environmental cooperation in the literature (Lee & Paik, 2020; Mitchell, 2010; O'Neill, 2009) and the lifecycle model of network/collaborative governance processes summarized in the collaborative governance literature (Imperial et al., 2016; Ulibarri et al., 2020), this study divides the three decades of development of collaborative mechanisms into three stages with three progressive goals of collaboration: information exchange, joint research and technical cooperation, and action plans (Figure 1). A brief introduction to each stage is presented below.

Stage 1 (1988–1992): Information exchange through embedded mechanisms

The first stage focused on exchanging information to identify shared regional environmental issues and stakeholders. It started in 1988 with

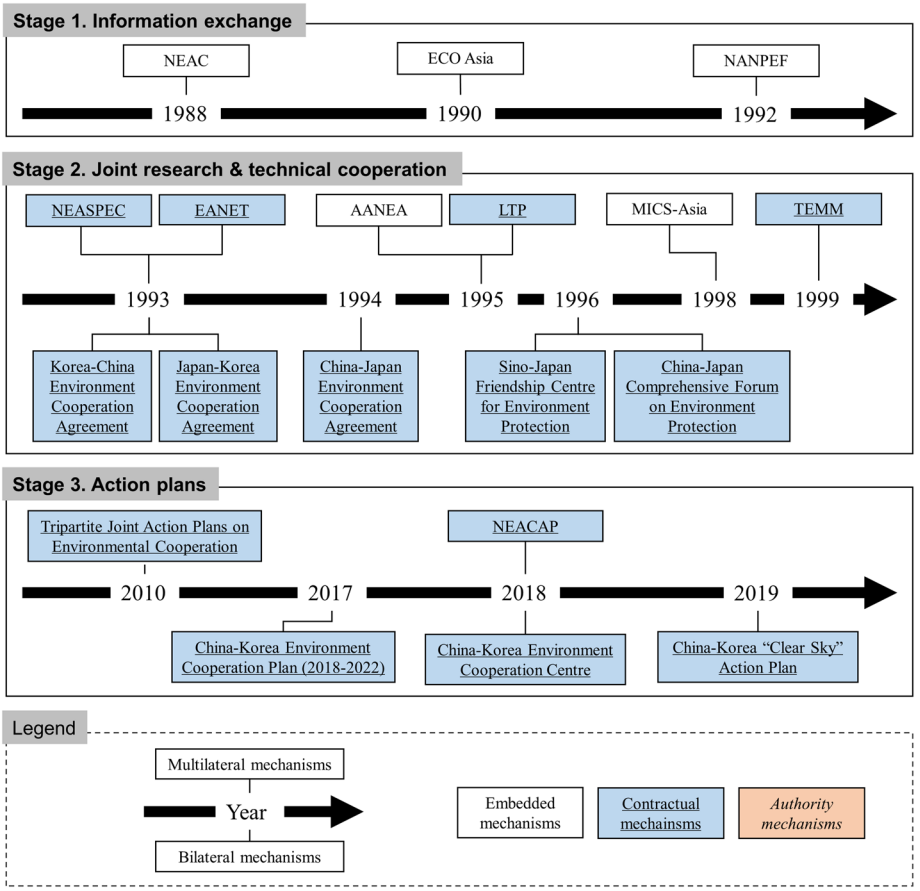

Figure 1. A diagram of the evolving collaborative mechanisms for addressing TAP in NEA. Note that the collaboration mechanisms at the top of the timeline are multilateral, while those at the bottom are bilateral. Mechanisms denoted using white boxes are embedded mechanisms, those with blue boxes and underlined text are contractual mechanisms, and those with red boxes and italicized text are authority mechanisms. The embedded mechanism, contractual mechanism, and authority mechanism are different types of collaborative mechanisms in ICA framework (see Section "ICA framework" for more details).

the first Japan-South Korea Environmental Symposium held in Seoul, South Korea, which facilitated the exchange of scientific and technological information on air pollution. In 1992, the symposium was renamed the Northeast Asian Conference on Environmental Cooperation (NEAC), in which environmental agencies and experts from NEA countries met annually to exchange information and explore possibilities for regional cooperation (Takahashi, 2001). Meanwhile, the Japanese Ministry of Environment initiated the Environment Congress for Asia and the Pacific (ECO Asia) to further promote the exchange of information on environmental management among East Asian environment ministers. In addition, non-governmental networks of scientific institutions and environmental experts from China, South Korea, and Japan, such as the Northeast Asia and

North Pacific Environmental Forum (NANPEF), played an active role in facilitating the exchange of information. These informal exchanges and dialogues between governmental officials and environmental scientists in various symposiums and forums led to a preliminary consensus on transboundary environmental governance collaboration and laid the foundation for more formal regional cooperation mechanisms.

Stage 2 (1993–2009): Joint research and technical cooperation through contractual mechanisms

After reaching a preliminary consensus on collaboration to address TAP, NEA countries began to focus on joint research and technical cooperation to identify the sources of TAP and its attribution. This involved long-term pollution monitoring and simulations to identify air pollutants of concern, how much exists, and where they come from and flow to. To achieve these objectives, NEA countries established several bilateral and multilateral collaborative contractual mechanisms. From 1993 to 1996, China, South Korea, and Japan signed bilateral environmental cooperation agreements to conduct joint pollution monitoring and research. For example, in 1996, the environment ministries of China and Japan jointly established the Sino-Japan Friendship Center for Environmental Protection and the Japan-China Comprehensive Forum on Environmental Cooperation. Moreover, Japan provided financial support for China's environmental protection projects through its official development assistance (ODA) program.

Several important multilateral contractual mechanisms were developed at this stage. In 1993, foreign and environmental ministers from NEA countries agreed to establish the Northeast Asian Subregional Programme for Environmental Cooperation (NEASPEC). Three years later, the ministers officially adopted the framework of NEASPEC. Although the agreement for the framework did not specify mandatory rules and responsibilities for participating countries (NEASPEC, 1996), it marked the first time that NEA countries reached an agreement on regional environmental cooperation. Another important multilateral mechanism is the Tripartite Environment Ministers Meeting (TEMM) attended by environmental ministers from China, Japan, and South Korea annually since 1999. Although TEMM does not involve any mandatory political or financial commitments, it has facilitated many cooperative projects and collaborative mechanisms, such as the Acid Deposition Monitoring Network in East Asia (EANET) and the Long-range Transboundary Air Pollutants in Northeast Asia (LTP).

EANET was initiated and funded by Japan in 1993 to address acid deposition in East Asia. The network has linked 62 monitoring sites from 13 Asian countries, including China, South Korea, and Japan. A similar initiative is the LTP, which was initiated by South Korea. Both initiatives

are contractual mechanisms because they have a formal inter-governmental organizational form and were set up with the collective consent and voluntary commitment of participating countries. For instance, EANET has established a formal organizational structure to govern its activities. This structure includes the Inter-Governmental (IG) meeting as its main decision-making body, the scientific advisory committee (SAC) which provides scientific advice, the Secretariat which supports the network activities in collaboration with participating countries' national focal points, and the Network Center which collects monitoring data. Regarding the financial arrangement for EANET, participating countries are not required to make a mandatory financial contribution, although they are encouraged to do so by Japan which contributed most of the budget (Kim, 2014).

Stage 3 (2010–present): Non-binding action plans through contractual mechanisms

As the collaboration on joint research and technical cooperation continued in the early 21st century, NEA countries, particularly South Korea and Japan, were dissatisfied with the nascent and rudimentary collaboration. They demanded concrete actions to reduce TAP. As a Korean scholar commented, "*most existing NEA environmental cooperation remains at the low-level of information exchange, the pollution monitoring methods are not compatible enough…many cooperation projects are duplicated with little concrete results*" (Lim, 2019). Japan also complained that the measures by China and South Korea on TAP were insufficient and called for concrete actions to mitigate pollution (Chiashi & Lee, 2020). Therefore, NEA countries started to take a more action-oriented approach. TEMM has developed three Tripartite Joint Action Plans on Environmental Cooperation (TJAPs) with the consent of participating countries since 2010. Similarly, NEASPEC has developed the NEASPEC strategic plan 2021–2025 to coordinate actions of participating countries in addressing TAP. The action plans and associated agreements are still voluntary, lacking mandatory compliance mechanisms and formal scrutiny of environmental practices.

Meanwhile, there have been new developments in the environmental collaboration between China, South Korea, and Japan. In 2010, China's GDP surpassed Japan's, leading to growing opposition in Japan to continuing ODA to China. Consequently, Japan's ODA to China rapidly decreased in recent years and came to an end in 2022. In 2012, the 18th National Congress of the Communist Party of China (CPC) officially included the idea of "Eco-Civilization" in the CPC's constitution. Consequently, environmental protection has become a policy priority for China with the nation's administration progressively allocating resources to combat pollution over the subsequent years. In addition, despite years

of joint research on sources of TAP and its attribution, NEA countries have not yet reached a consensus on scientific findings of source areas' contributions to TAP and associated responsibilities (Liu et al., 2022). This disagreement has led to the recurrence of finger-pointing and diplomatic tensions among NEA countries. For instance, in 2019, South Korean Ministry of Environment alleged that China accounted for 70-80% of Seoul's particulate matter (PM) pollution. However, officials from the Chinese Ministry of Environment refuted the allegation, stating that China was not responsible for South Korea's pollution problems (Koyanagi, 2019).

Findings

The overview of the case above shows that the transnational environmental collaboration on TAP in NEA over the past three decades can be divided into three stages with three interconnected and progressive collaboration goals: information exchange, joint research and technical cooperation, and action plans. Initial collaboration required building mutual trust and shared understanding, particularly in a region with no prior transnational environmental cooperation, which was achieved through informal information exchange (Stage 1). However, alleviating TAP requires more than just dialogue. Before making efforts and taking collaborative actions (stage 3), shares of responsibility have to be allocated to determine the costs and burdens for each participating actor. Therefore, joint scientific research (stage 2) has to be carried out to identify the source areas of TAP and quantify the source contributions of each actor. This three-stage trajectory model is consistent with the lifecycle model of network/collaborative governance processes summarized in the collaborative governance literature (Imperial et al., 2016; Ulibarri et al., 2020).

In order to achieve the three progressive collaboration goals, NEA countries employed informal embedded mechanisms for information exchange, contractual mechanisms for joint research and technical collaboration, and contractual mechanisms for action plans at each collaboration stage. Why did NEA countries choose these collaborative mechanisms at different stages? Why did they not select a more formal and authoritative approach, like delegated authority at the third stage to address TAP more effectively? Case analysis shows that national state actors' choices of collaborative mechanisms were driven by their assessment of the collaboration risk and perceptions of the transaction costs associated with different options of mechanisms at each stage.

In summary, we have identified three unique sources in the transnational environmental collaboration context that contribute to collaborative risk as the transnational environmental collaboration on TAP progresses to later stages: the complexity and uncertainty of TAP scientific research, the

diplomatic dimension of the international collaborative governance on transboundary environmental issues, and the heterogeneity in economic development among actors (Section "Sources of collaboration risk"). As the collaboration progresses from information exchange to joint research and eventually to action plans, more sources of collaboration risk emerge, and as a result, the collaboration risk increases in later stages. Problems of incoordination, unfair division, and defection may arise, which makes the collaboration more likely to fail. Consequently, in order to reduce increasing collaboration risk, NEA countries are motivated to consider choosing more formal and coercive mechanisms (Section "Impact of collaboration risk on actors' choices of collaborative mechanisms"). However, such mechanisms often entail higher transaction costs. When the costs outweigh benefits and no resource exchanges offset them, actors opt to retain previously functioning informal mechanisms rather than adopting costly formal ones (Section "Constraint of transaction costs on actors' choices of collaborative mechanisms"). A conceptual model is produced based on the findings in this paper (Figure 2).

Sources of collaboration risk

Understanding the sources of collaboration risk in different contexts can help identify unique features of the contexts that may contribute to collaboration failure. This information can help inform solutions to reduce the collaboration risk and promote successful and effective collaboration. We find that the collaboration risk in the context of transnational environmental collaboration on TAP is rooted in three sources: the complexity and uncertainty of TAP scientific research, the diplomatic dimension in international collaboration on TAP, and the heterogeneity in economic development among actors.

The complex and uncertain nature of TAP scientific research

The level of collaboration risk is shaped by the nature of the ICA problem (Feiock, 2009; Feiock, 2013). In transnational environmental governance, scientific uncertainty in identifying pollution sources and quantifying

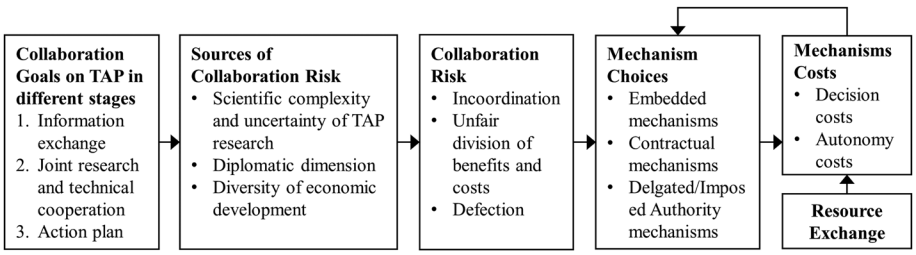

Figure 2. A conceptual model for understanding the evolving collaborative mechanisms in transnational environmental collaboration on TAP.

contributions directly elevates collaboration risk, as actors struggle to agree on cost allocation without credible evidence, particularly when there is incomplete and uncertain information on the allocation of costs and burden in dealing with the ICA problem.

During the second stage of collaboration on TAP in NEA, efforts to define pollution sources and responsibilities faced critical challenges due to the complexity, fluidity, and multi-directionality of TAP. The current scientific understanding of the emission, transport, chemical transformation, and deposition processes of TAP is limited and imperfect. As a result, scientific findings on source contributions have large uncertainties and vary considerably depending on the computational models, time periods, data, metrics, and analysis perspectives chosen. For example, scholars have produced varying results regarding the allocation of responsibility for addressing TAP in NEA, depending on different metrics such as pollutant concentrations and premature deaths, as well as different accounting perspectives, including the production and consumption perspective (Liu et al., 2025).

This uncertainty was amplified by fragmented and politicized scientific communities in China, South Korea, and Japan (Shapiro & Yarime, 2021; Yarime & Li, 2018). To avoid alienation from expert communities in their own countries, scholars in NEA countries may be motivated to use specific data, models, metrics, and analysis perspectives to highlight or understate the contributions of source countries to TAP in receptor countries and reach conclusions that are favorable to certain countries. To make things worse, scholars in China, South Korea, and Japan rarely collaborated on scientific research, probably because actors with power disparity usually do not have scientific and technical information exchange in the adversarial policy network (Lee et al., 2025). These politicized findings are handpicked by politicians, media, and advocacy groups in NEA countries to prioritize certain results over others (Shapiro & Yarime, 2021), and therefore support their claims on responsibility allocation. This is consistent with what Lee and Huang have found in their study that technical information is politicized as a weapon to argue against opposing coalitions (Lee & Huang, 2023). For example, an interviewee with expertise on air pollution research shared with us his observation on scientific studies on TAP in NEA:

> Those short-term studies that use outdated emissions inventory data, or lack international cooperation, often by South Korean or Japan scholars, usually concluded that China contributed a higher proportion of transboundary particulate pollution. Conversely, studies by Chinese scholars usually concluded that China's contribution is smaller than expected. *(a researcher specialized on air pollution at a research institute in Beijing)*

The attribution of responsibility for addressing TAP is a sensitive issue for NEA countries, as the division of responsibility for pollution directly affects the distribution of costs in collective action. Disagreements over responsibility allocation have triggered conflicts across the public, media,

and governments in NEA, even within existing collaborative mechanisms. For example, during the 20th inter-governmental meeting of EANET in 2018, some national state actors argued against the inclusion of analysis on attribution of the pollutant source in the report for policy makers:

> Several comments were focused to the proposed deletion of the sections introducing a scientific research analysis on attribution of the source of pollutants in geographical areas…After the discussion, proposed deletion was accepted to avoid raising sensitive matters. In the future, it is suggested that scientific judgement could be discussed in SAC before IG. (EANET, 2018)

SAC here refers to the scientific advisory committee in the EANET, which provides scientific advice for national state actors. Ideally, if there is an existing international scientific institution which these national state actors previously participated in and interacted with, just like the European Monitoring and Evaluation Program (EMEP) in Europe (Haas, 2015), the scientific institution could provide authoritative scientific advice and the uncertainty of TAP research could have been reduced. The ICA literature suggests that existing networks or institutions may be catalysts for later collaboratives (Tavares & Feiock, 2018), because previous networks or institutions can breed trust and credible commitments that increase the efficiency in establishing a collaboration (Kwon et al., 2014). Apparently, the SAC in the EANET can hardly function as such an institution recognized internationally by all actors. As a result, the absence of such an institution in NEA has made it difficult to prevent the complexity and uncertainty of TAP research from increasing collaboration risk.

In summary, the complexity and uncertainty of TAP scientific research have made it very difficult to determine with confidence the source areas of the pollution and quantify the impacts and associated responsibilities. This uncertainty, combined with politicized and fragmented epistemic communities in NEA countries and the absence of recognized scientific advisory institutions, has resulted in a lack of consensus among actors on TAP and led to recurring finger-pointing and conflicts, increasing the likelihood of coordination failure.

Diplomatic dimension of the international collaborative governance on transboundary environmental issues

Transnational TAP governance inherently relies on national governments, making inter-state relations critical for effective collaboration. TAP is not merely an environmental issue but a diplomatic one, with international cooperation serving as a tool of environmental diplomacy to advance national interests (Dimitrov, 2014). This is particularly evident in NEA, where foreign ministries often initiate TAP-related forums. For state actors, collaboration goals extend beyond pollution mitigation to include enhancing national prestige and influencing regional institutions. These goals

intensified the competition for leadership. In the case of TAP in NEA, Japan preferred to promote EANET as the primary monitoring mechanism However, South Korea raised concerns about the transparency of the network center of EANET as the meeting agenda was dominated by Japan and most personnel in EANET were from Japan. Instead, South Korea attempted to advance intergovernmental cooperation through mechanisms such as LTP to compete against Japan (Kim, 2014). The competition and opposition between Japan and South Korea have resulted in overlapping mechanisms and coordination failures, increasing the risks of cooperation.

The diplomatic prestige and influence can be seen as a kind of selective benefit for national state actors in addition to the collective benefit on addressing TAP. Feiock and Carr (2001) described and summarized various kinds of selective benefits in the ICA literature, including prestige, greater influence, status, political power, job protection, etc. According to Feiock (2007), selective benefits provide incentives for actors and motivate actors to take collective action and promote regional cooperation. However, our study shows that, in the context of transnational environmental collaboration in NEA, selective benefits such as diplomatic prestige and leadership may have a negative impact on the collaboration. As an interview participant specialized in environmental management in Beijing described, the competition for prestige and leadership in TAP governance collaboration between Japan and South Korea is "*a bargaining process fighting for political dominance, negatively affecting the regional cooperation*." A possible reason is that, for national state actors, the benefits of international leadership and diplomatic prestige can hardly be shared but mostly captured by the dominant country to promote its own international policy agendas. Therefore, whether the selective benefits promote collaboration depends on the exclusiveness of the benefits behind.

In addition to the coordination problem discussed above, diplomatic volatility compounded these risks. Historical and territorial tensions in NEA mean that deteriorating Sino-Japanese or Sino-South Korean or Japanese-South Korean relations often derail environmental collaboration. As Lim (2019) observes, territorial disputes frequently lead to the postponement or cancelation of existing TAP initiatives.

Heterogeneity in economic development among actors

Economic heterogeneity among actors and divergent economic preferences significantly influence collaboration risk. ICA literature highlights that economic asymmetries create heterogeneous demands in cooperation negotiations (Feiock, 2013). This heterogeneity places actors in divergent positions, makes cost allocation bargaining more difficult (Feiock, 2007), and thus reduces collaboration success rates (Feiock, 2013; Tavares & Feiock, 2018). In NEA, the difference in economic development among China,

South Korea, and Japan has led to different positions and differing policy priorities on collaborative governance for TAP. As developed nations and TAP "victims," Japan and South Korea have actively pushed for regional mechanisms. Compared to South Korea and Japan, China faces a greater challenge in balancing economic growth and environmental protection. For a long time before the 18th CPC National Congress held in 2012, China had prioritized economic development over environmental protection (Liu & Li, 2024). For example, in a speech at the 1992 United Nations Conference on Environment and Development, the late Chinese premier Li Peng stated:

> Economic development provides material support for environmental protection. For many developing countries [including China], economic development and poverty eradication are the top priorities. *(*Li, 2010*, p. 230)*

As a result, China took a defensive position for a long time and was hesitant to bear the costs of pollution abatement (Komori, 2010). Despite China's shift toward "green development" in recent years, which accelerated domestic pollution mitigation, consensus remains elusive. Concurrently, as China's GDP surpassed that of Japan and South Korea after 2010, Japan and South Korea have held the expectation that China should take on a more significant role in addressing TAP (Chang, 2018). However, China argued for fairer cost distribution "*in a fair, inclusive and just manner with full consideration of common but differentiated responsibilities*" (NEASPEC, 2022). Institutional differences compound these tensions: Japan and South Korea's systems prioritize electoral representation and decentralized governance, whereas China's centralized governance enables unified national action. These institutional differences shape their respective policy approaches, priorities, and positions on transnational environmental collaborations. Such divergences hinder shared goals in NEA environmental collaborations, increasing the risk of incoordination and unfair division of costs.

Impact of collaboration risk on actors' choices of collaborative mechanisms

The three sources of collaboration risk identified above resulted in varying levels of collaboration risk at different stages of the collaboration, which motivated NEA countries to consider using different collaborative mechanisms at different stages (Table 1). At the first stage, NEA countries did not need to make promises, coordinate a broad array of activities, or discuss the allocation of benefits and costs. In other words, actors found that the risks of incoordination, unfair division, and defection were very low, and they did not need a formalized mechanism to exchange information. Instead, information exchange can be achieved through informal networks with flexible rules and a simple

Table 1. Changing collaboration risk and mechanism costs in the international collaboration on TAP in NEA.

Collaboration goals on TAP in different stages	Sources of collaboration risk	Level of collaboration risk	Mechanism choices under consideration to reduce the collaboration risk	Mechanism costs for the mechanism choice under consideration		Resource exchange to offset mechanism costs	Expected costs for the mechanism choice under consideration (mechanism costs less resource exchange)	Chosen mechanisms
				Decision costs	Autonomy costs			
Stage 1. Information exchange	Almost none	Low	Embedded mechanisms	Low	Low	Low but increasing	Low	Embedded mechanisms (e.g., ECO-ASIA, NEAC)
Stage 2. Joint research and technical cooperation	1. Diplomatic dimension of the international collaboration on TAP 2. Diversity of economic development among actors	Medium	Contractual mechanisms	Medium	Low	High	Low	Contractual mechanisms (e.g., NEASPEC, TEMM, EANET)
Stage 3. Action plans	1. Complexity and uncertainty of TAP scientific research 2. Diplomatic dimension of the international collaboration on TAP 3. Diversity of economic development among actors	High	Delegated authority mechanisms	High	High	Very low and decreasing	High	Contractual mechanisms (e.g., Tripartite Joint Action Plans, China-Korea "Clear Sky" Action Plan)

organizational form. Therefore, at the first stage, NEA countries preferred informal networks in the form of conferences and symposiums, such as NEAC, ECO Asia, and NANPEF, to collaborate on information exchange.

At the second stage, NEA countries realized the collaboration risk increased, and as a result, informal embedded networks were inadequate for implementing and sustaining collaboration on joint research and technical cooperation. They needed a more formal mechanism than the embedded mechanism—contractual mechanisms—to reduce the risk. On the one hand, implementing joint research and technical cooperation requires the collection of data from all NEA countries, which demands the prior consent and coordination of all governments in NEA countries. Informal networks are clearly insufficient to handle such complex and arduous tasks of coordinating different governmental agencies at multiple levels from various countries. Due to the diplomatic nature of cross-border cooperation and the different positions of actors on environmental cooperation, the risk of incoordination among actors in informal networks may increase. On the other hand, the asset specificity of the investment of human resources and physical equipment during joint research and technical cooperation may have an impact on collaboration. According to Williamson (1991), asset specificity, which is the degree to which transaction-specific investments can be easily redeployed to other uses, plays an important role in influencing actors' choices in governance mechanisms. An investment with high asset specificity cannot be readily adapted for alternative uses. Consequently, an actor who makes the investment with high asset specificity is usually vulnerable to extra costs and faces higher risk if other actors withdraw (Feiock, 2007). In NEA, national state actors, particularly Japan and South Korea, were aware of the need to invest in specialized human resources, financial input, and physical equipment to enforce pollution monitoring, joint research, and technical cooperation. These investments were highly asset specific and difficult to adapt or redeploy for other purposes. If one participating country reneges, other countries would suffer significant losses, and the consequences would be severe. As a interviewee noted:

> Japan contributed the largest share of the cost of building a network for monitoring acid deposition and dust storms in early 2000s. These expenditures include equipment for monitoring, data transmission equipment, manpower and maintenance. Japan has contributed so much, surely in the hope of promoting further cooperation and friendly exchanges *(A researcher specialized on climate change and air pollution in Asia at a university in Hong Kong)*

At the third stage, NEA countries demanded concrete actions to reduce TAP. They realized that the collaboration risk for the action plans at the

third stage would further increase compared with that at the second stage (Table 1). Due to the complexity and uncertainty of TAP scientific research, years of joint research at the second stage have not yet produced a consensus on the sources of TAP and its attribution. Instead, they have led to recurring disputes between governments, media, and the public in NEA (Koyanagi, 2019). The social capital and trust accumulated in previous stages play a limited role in reducing the disputes and conflict at this stage. As a result, NEA countries have been unable to agree on the allocation of responsibilities and associated costs, increasing the likelihood of collaboration failure on action plans. When there are disputes and conflicts among participants, more authoritative mechanisms with enforcement may be needed to produce effective collaborative agreements on actions (Tavares & Feiock, 2018).

To reduce the collaboration risk in enforcing the action plans on TAP, NEA countries began considering a sufficiently institutionalized and more authoritative mechanism, such as the delegated authority mechanism. In 2009, an international team of ten policy researchers from three national leading environmental think tanks[2] in China, South Korea, and Japan, sponsored by the environmental ministries in each country, jointly proposed the establishment of a regional environmental authority as the central entity for managing and operating the collaboration. They recommended that EANET should develop mandatory and legal instruments with mandatory financial contributions, similar to the EMEP, to implement active measures and policies against TAP (Tian et al., 2009, p. 176). They called for a more binding regional convention agreement on TAP, similar to the Convention on Long-range Transboundary Air Pollution (CLRTAP).

In summary, NEA countries have considered using an authority mechanism to address uncertainties and behavioral risks such as shrinking and defection at the third stage. However, NEA countries did not opt for authority mechanisms at the third stage. Instead, they continued to use contractual mechanisms. Why? We find that, in addition to the collaboration risk, the transaction costs associated with the mechanism under consideration have limited actors' choice of more coercive and authoritative mechanisms, which is elaborated in the next section.

Constraint of transaction costs on actors' choices of collaborative mechanisms

Table 1 presents a comparison of the transaction costs associated with the three mechanism choices under consideration at different stages (see the column labeled "Mechanism costs for the mechanism choice under consideration"). At the first stage, NEA countries considered using informal

embedded mechanisms due to the low collaboration risk, and they finally chose the embedded mechanisms because of the low decision costs and autonomy costs associated with the embedded mechanisms. NEA countries found that participation in embedded mechanisms does not require political commitment or sovereignty ceding, preserving the autonomy of national governance. The informal, flexible nature of these mechanisms also enables low-cost cooperative negotiations.

At the second stage, rising collaboration risks prompted NEA countries to adopt contractual mechanisms. However, the contractual mechanisms have higher transaction costs than the embedded mechanisms, as the contractual mechanisms require negotiating formal intergovernmental agreements and allocating financial, human, and material resources for joint research and technical cooperation. For example, NEASPEC member countries are required by its senior officials' meeting to make financial contributions to support the implementation of its activities. Despite the higher costs of contractual mechanisms, NEA countries chose them for stage two collaboration because resource exchanges significantly mitigated perceived costs. In a typical negative externality problem, actors who impose a negative externality on their neighbors have no incentives to change their behaviors because these actors benefit from supplying the negative externalities (Feiock, 2013). As previously discussed, due to the priority of economic growth, China initially lacked the motivation to take actions to mitigate pollution (Xue & Zhang, 2013). To address this challenge, Japan proposed compensating China through its ODA programs to ensure China's participation (Mori, 2016). Since the mid-1990s, Japan has provided grant aid and loans to China to implement environmental protection projects in Chinese cities. In 2000, South Korea also provided financial support to China for the restoration of forestry in western China, although the amount was much less than that of Japan. These aids and loans significantly reduced the costs China perceived in engaging in the international collaboration on TAP in NEA. Moreover, China's efforts to improve its global image as a responsible environmental actor and avoid the stigma of irresponsibility drove its active involvement in contractual mechanisms. As a result, NEA countries adopted the contractual mechanisms for collaboration at the second stage.

At the third stage, NEA countries considered using the authority mechanisms. However, due to the high mechanism costs associated with the authority mechanisms and the significant decrease in resource exchange that can offset these costs, NEA countries perceived that the expected costs were high. As a result, NEA countries continued to rely on the contractual mechanisms to carry out collaboration of action plans. On one hand, the loans from Japan ceased in 2008 and the grant aids decreased significantly since 2010 when China's GDP surpassed Japan's. Financial

support from South Korea also became insufficient and negligible (Lee & Paik, 2020). Meanwhile, Japan began to request that China bear part of the expenses for technical cooperation (Chang, 2018).

On the other hand, authority mechanisms, which involved legally binding agreements, mandates, and forced environmental responsibilities, were viewed as more expensive than the contractual mechanisms used at the second stage (see Table 1). Some countries, such as South Korea, resisted binding cooperation, fearing that "*the binding cooperation will make clear its responsibility for Japan*" (Yoon, 2007). Similarly, China was also reluctant to accept the cost (Komori, 2010). More importantly, NEA countries were concerned that authority mechanisms would undermine national sovereignty by requiring them to delegate environmental policymaking and enforcement powers. For example, the Chinese government has stated clearly that "*International environmental cooperation must be based on mutual respect for national sovereignty*" (Chinese State Council, 2005). Consequently, the authority mechanisms became unfeasible.

Discussion and conclusion

This paper presents an updated and comprehensive summary of the collaborative mechanisms established by NEA countries to address TAP over the past three decades and explains why NEA countries selected these collaborative mechanisms over time. It identifies three stages of collaboration with three interconnected and progressive goals achieved through different mechanisms: (1) information exchange through informal embedded mechanisms at the first stage (1988–1992), (2) joint research and technical cooperation through contractual mechanisms at the second stage (1993–2009), and (3) non-binding action plans through contractual mechanisms at the third stage (2010–present).

The selection of these mechanisms over time is influenced by NEA countries' perceptions of collaboration risks and their assessment of transaction costs. Specifically, three sources of collaboration risk shape the likelihood of failure in transnational environmental collaboration: (1) the complex and uncertain nature of TAP scientific research, (2) the diplomatic dimension of international collaborative governance on TAP, and (3) the heterogeneity in economic development among actors. The theoretical origins for the three sources can be traced back to several important underpinning concepts in the ICA framework, including the nature of the ICA problem, actor preferences, existing institutions, and selective benefits. The three sources have produced varying levels of collaboration risk at different stages of collaboration. Generally, the collaboration risk increases as the collaboration progresses from information exchange to joint research and then to action plans, because more sources of collaboration risk

emerge. As collaboration risk increases, actors tend to adopt more formal, authoritative, and coercive mechanisms to mitigate opportunistic behavior. Without considering the transaction costs, national state actors tend to use embedded mechanisms at the first stage of information exchange, contractual mechanisms at the second stage of joint research and technical cooperation, and authority mechanisms at the third stage of action plans. However, if the costs of the mechanism being considered are too high for actors to afford and there are no resource exchanges that can offset these costs, actors are likely to revert to the previously functioning but less formal mechanism. This explains why NEA countries did not adopt the authority mechanisms at the third stage, but instead opted for the contractual mechanisms.

Findings of this study have important theoretical and practical implications. First, it extends the ICA framework beyond local governments to transnational environmental collaborations involving national state actors. Unlike local collaborations, which are often mandated or facilitated by higher-level authorities in an explicit or implicit way (Chen et al., 2019; Hawkins et al., 2016; Liu et al., 2024; Suo et al., 2023), transnational collaborations often lack such overarching authorities. Moreover, the relationships between national state actors are more complex than those between local actors. Thus, it is crucial to assess whether the ICA framework holds across different types of collaborations and institutional contexts.

In particular, upon applying theoretical concepts in the ICA framework such as the nature of the ICA problem, actor preferences, existing institution, and selective benefits, this study identifies three unique sources of collaboration risk in transnational environmental collaboration and explicates how these sources contribute to the likelihood of collaboration failure in the context. Our findings challenge some theoretical predictions in the ICA framework, suggesting the need for further theoretical development. For instance, while the ICA framework suggests that selective benefits incentivize collective action (Feiock, 2007), this study finds that, in the context of transnational environmental collaboration, selective benefits such as diplomatic prestige and leadership may negatively affect collaboration. We argue that the impact of selective benefits depends on their exclusivity, highlighting the need for more empirical research on their role in collaboration.

In addition, previous ICA literature has proposed that the social capital and trust generated by embedded collaboration during previous collaboration process help reduce the collaboration risk at the next stage of collaboration (Deslatte & Feiock, 2019; Hawkins et al., 2016). However, the NEA case in this study shows that the social capital and trust built from prior stages have limited impact on mitigating collaboration risks in later stages. This is because the three identified sources of

collaboration risk significantly shape collaboration outcomes in transnational environmental collaboration contexts, making social capital and trust less effective in reducing these risks. For example, although Japan, South Korea, China, and other countries jointly established EANET in 1993 to identify the sources of TAP and its attribution, no scientific consensus has emerged over two decades, with social capital and trust failing to prevent recurring disputes over responsibility. Additionally, turnover in governments and officials can erode social capital, further weakening its role. Social capital and trust are often disregarded by national state actors in the defense of national interests and competition for leadership and diplomatic influence.

Second, this study echoes the recent call for more research on temporality and evolution of integration mechanisms (e.g., Kim et al. (2022)), and contributes to the ICA literature by integrating the ICA framework with a three-stage developmental trajectory model derived from the lifecycle of network/collaborative governance processes from the collaborative governance literature (Imperial et al., 2016; Ulibarri et al., 2020). Most previous ICA studies are cross-sectional, and only a few studies have examined the evolution of collaborative mechanisms (Chow et al., 2023; Hawkins et al., 2016; Woods & Bowman, 2018), they often focus on specific factors or limited mechanism types at certain stages. Based on a dataset consisting of meeting minutes, policy announcements, reports, memoirs of officials, and other data over the past three decades, this longitudinal case study investigates a variety of collaborative mechanisms and the changing actors' assessments of collaboration risk and mechanism costs at different collaboration stages, and provides a comprehensive explanation of the factors influencing actors' evolving choices of collaborative mechanisms.

Third, by drawing on the ICA framework, this study offers a clear and integrated understanding of the history, current status, and future prospects of international collaborative governance on TAP in NEA. Based on our findings, it can be inferred that the environmental collaboration among NEA countries will likely continue to rely on contractual mechanisms due to the high costs associated with authority mechanisms, especially the perceived autonomy costs. It is argued that China's climate commitment will likely improve air quality in its own and neighboring countries over the next few decades through comprehensive adjustments in energy systems and industrial restructuring (Tang et al., 2022). Therefore, a binding regional environmental collaboration mechanism for TAP mitigation may be unnecessary in NEA, as non-binding agreements would likely achieve the same goals through domestic pollution mitigation policies.

Lastly, the international collaboration on TAP in NEA provides valuable lessons for regions facing emerging transboundary environmental

challenges, particularly those with significant economic, political, and socio-cultural differences. Our findings suggest that decision-makers should adopt a longitudinal perspective and consider evolving temporal dynamics in collaborative governance for ICA problems. We highlight that a transnational environmental collaboration usually consists of three stages with three interconnected and progressive goals: information exchange, joint research and technical cooperation, and action plans. Each collaboration stage has different levels of collaboration risk due to the three sources of collaboration risk identified in this study. Therefore, it is suggested that actors in these regions should be aware of the three sources of collaboration risk that emerge at different collaboration stages and take measures to mitigate the negative effects.

There are several future research directions to address the limitations of our study. Firstly, the theoretical findings of the evolving international collaborative mechanisms on TAP that were built based on the case study of the NEA and ICA framework need to be quantitatively tested. Secondly, comparative studies are needed to test whether the three sources of collaboration risk apply to transnational collaborations across different environmental policy areas (e.g., transboundary water resource management, biodiversity conservation, etc.) and geographic regions (e.g., Southeast Asia, the Arctic Circle, etc.) and whether there is a universal theoretical model of the sources of collaboration risk in these contexts. In addition, future research should include a comparative analysis of TAP governance across the NEA, ASEAN, Europe, and the Americas, considering the temporal development of governance mechanisms and explaining regional differences and similarities. This longitudinal comparison could use the ICA framework or the Advocacy Coalition Framework which provides a range of useful conceptual tools such as advocacy coalitions, beliefs, policy brokers, and internal and external shocks (Sabatier & Jenkins-Smith, 1993). Thirdly, this study focuses solely on national state actors. However, international environmental collaboration is inherently multilevel and polycentric (Papadopoulos, 2025). Future research may apply social network analysis to explore cross-level relationships, information exchange, and their impact on collaboration, identifying barriers or catalysts at different stages.

Notes

1. The typical transboundary air pollution problems in Northeast Asia include dust and sandstorm (DSS), acid rain, and particulate matter (PM) pollution.
2. The three think tanks are Policy Research Center for Environment and Economy of Chinese Ministry of Environment and Ecology, Institute for Global Environmental Strategies of Japan, and Korea Environment Institute.

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Notes on contributors

Jianzheng Liu is an associate professor at the School of Public Affairs of Xiamen University. His research interests include emergency management, environment and sustainable development. He architected the study, collected and analyzed the data, prepared the figures and tables, and crafted the manuscript draft.

Wang Zhang is a graduate student at the School of Public Affairs at Xiamen University. His research focuses on emergency management and collaborative governance. His contributions include data collection, data interpretation, and crafted the manuscript draft.

Peiling Zhou is an associate professor in Department of Urban Planning at Harbin Institute of Technology, Shenzhen. Her research interests include health geography, healthcare management, publicness, and health equity. Her contributions include data interpretation, validation, and manuscript refinement.

Jiawei Li is a professor of the Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP, CAS). His research interests involve air quality modeling, aerosol-meteorology interaction, and natural aerosol emission mechanism. His contributions include data collection and data interpretation.

Tian Feng is a research professor at the Department of Geography & Spatial Information Techniques, Ningbo University. His research interests include atmospheric chemistry and physics associated with air pollution, interactions between air pollution and the climate, and greenhouse gases transport and exchanges with the terrestrial ecosystems. His contributions include data collection and data interpretation.

Hongyan Zhao is an associate professor of the School of Environment at Beijing Normal University. Her interests involve input-output analysis, environmental planning, and atmosphere environment management. Her contributions include data collection and data interpretation.

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