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Exploring Coordinative Mechanisms for Environmental Governance in Guangdong-Hong Kong-Macao Greater Bay Area: An Ecology of Games Framework

Wenjie Zhou and Rui Mu *

Faculty of Humanities and Social Sciences, Dalian University of Technology, Dalian 116024, China; zhouwenjie@dlut.edu.cn

* Correspondence: ruimu@dlut.edu.cn; Tel.: +86-0411-8470-7479

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Abstract: To solve regional environmental problems, there is a trend of establishing urban agglomerations and formulating cooperative policy institutions in China. The extant studies on policy institutions largely focus on the coordinative mechanisms of multiple actors within one single institution. Only a few studies have tried to understand how different policy institutions are interlinked and mutually affected to influence actors' decisions and problem resolutions. This article applies a network-based analytical approach and adopts the Ecology of Games Framework to explore how regional environmental governance is coordinated in the Guangdong-Hong Kong-Macao Greater Bay Area. It was found that coordinative mechanisms in regional environmental governance can happen around three elements: policy institutions, policy actors, and policy issues. Policy institutions tend to serve as an umbrella for many diverse and interdependent activities and actors within individual institutions. Additionally, positive externalities emerging between different policy institutions perform as coordinators across institutions. For actors, state-level actors usually play as facilitators of policy institutions while they are not active in participating in policy games in later phases; it is regional actors, particularly from Guangdong, that are active in the operation of policy institutions. For policy issues, they emerge because they are often tied with each other, and some of them play as the common ground for seemly separating policy institutions.

Keywords: coordination; environmental governance; Guangdong-Hong Kong-Macao; Ecology of Games Framework

1. Introduction

With numerous overlapping jurisdictions across two semi-autonomous and highly developed cities (Hong Kong and Macao) and one economically dynamic province (Guangdong) that contains 21 prefecture-level cities, the Greater Bay Area (GBA) is an institutionally complex setting for environmental governance [1]. The GBA is a highly urbanized city cluster, with an average inter-city distance shorter than 10 km, which makes the prevention and control of transboundary air pollution a severe challenge [2]. Water quality is also a pressing concern [3]: the region's rivers serve the water needs of nearly 60 million inhabitants and 1.3 trillion USD economic activities every year. Moreover, the two cities, Hong Kong and Macao, rely primarily on the Dongjiang River in Guangdong for water supply based on the long-term contract with the mainland. Given this situation, there is an increasing risk that environmental pollution originating from any of the cities in the GBA, if it remains uncontrolled, will converge and turn into a significant region-wide problem [4].

By recognizing the transboundary nature of environmental pollution in the GBA, the environmental authorities in Hong Kong and Guangdong started to contact with each other in 1983 and have developed several regionally based policy institutions for coordinated environmental planning and decision-making. For instance, the first policy institution is the Guangdong–Hong Kong Environmental Protection Liaison Group, which was established in 1990 and upgraded to the Guangdong–Hong Kong Joint Working Group on Sustainable Development and Environmental Protection in 2000. However, this liaison group is not the only cooperative institution. In fact, our empirical study discovers 12 policy institutions that were established during 1985–2018 in the GBA, directly or indirectly aiming for regional environmental governance. In these policy institutions, actors with different or even competing interests come together, discuss, negotiate and make policy decisions on environmental issues.

The extant studies on policy institution largely focus on the coordinative mechanisms of multiple actors within one single institution or the pattern of actor interactions within a specific regional project [5–9]. Only a few studies have tried to understand how different policy institutions are interlinked and mutually affected to influence policy outcomes [10–12]. In this article, we follow in the opinion that the policy institutions that exist at a particular time and place may generate interdependent effects and combine to define the complex institutional system of environmental governance. Instead of focusing on one policy institution at a time, the regional environmental governance is the function of decisions made in multiple concurrent policy institutions. Therefore, the article answers the question: how regional environmental governance in the Guangdong-Hong Kong-Macao GBA is coordinated across multiple interdependent collaborative policy institutions?

To answer the question, we rely on the Ecology of Games Framework (EGF), which was first proposed by a sociologist Norton Long [13] who depicts urban systems as "ecology of games" that consist of multiple games played simultaneously by actors intending to achieve their individual goals and interests. The EGF is useful for our purpose because: (1) it specifically aims at analyzing sustainability issues, including ecological and environmental protection problems, which fits our research field of environmental governance, and (2) it draws explicit attention to interdependence of policy institutions at different geographic scales ranging from local to global, which is an important starting point for exploring and interpreting coordinative mechanisms among multiple actors that address a myriad of interconnected issues [14].

The article is structured as follows. Section 2 presents the EGF in detail, including its main conceptual elements and potential theoretical arguments. Section 3 introduces the case area, the methods we used to operationalize the EGF and our data collection and processing strategies. Section 4 displays the empirical findings. Section 5 discusses our findings and concludes the article and points out future research agenda.

2. The Ecology of Games Framework

2.1. Structural Elements in the EGF

The EGF is built upon five structural elements: policy institutions, policy actors, policy issues, policy games, and policy systems. The rest of this section describes these conceptual terms in more detail, using Figure 1 as an illustration.

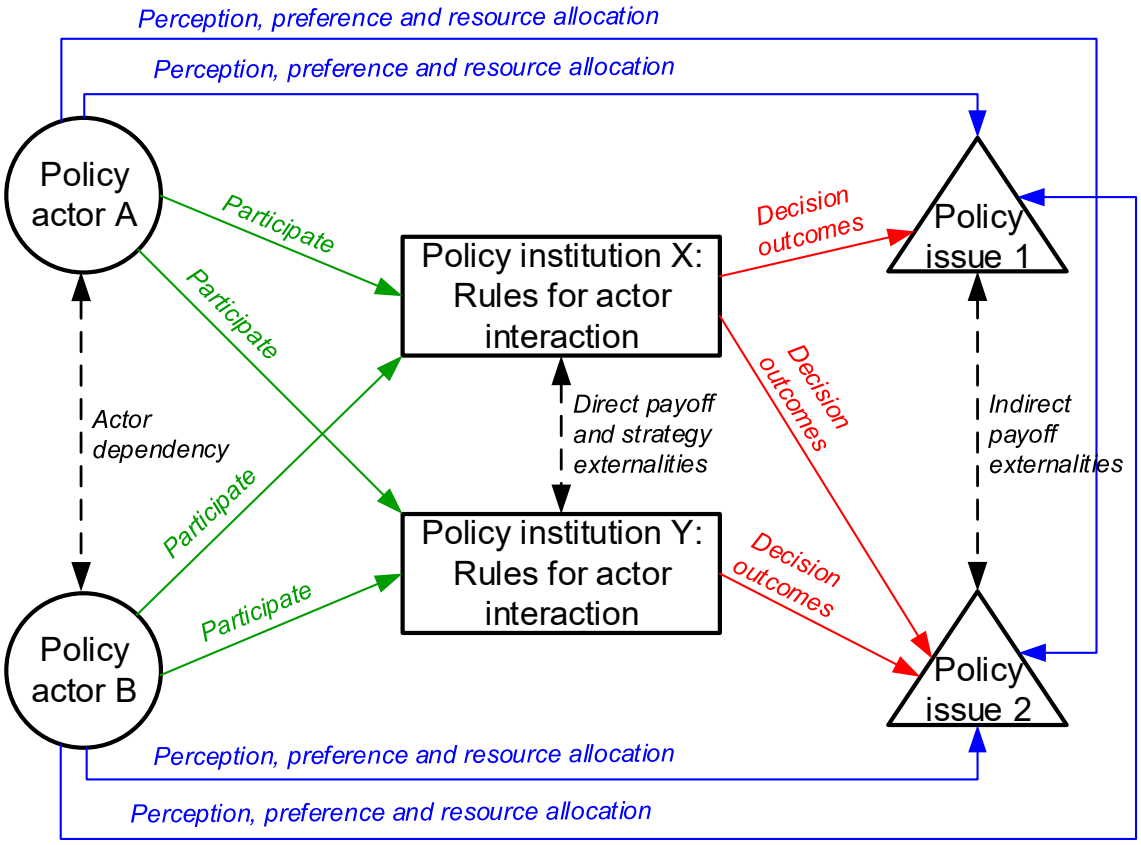

Figure 1. The Ecology of Games Framework (adapted from Lubell [15,16]).

Actors may be any kind of meaningful social unit, including individuals, collective entities, firms, government and non-government organizations, and divisions within organizations, as well as nonhuman agents, such as knowledge repositories [17]. Policy actors refer to those actors that are involved in policy processes and whose choices and actions will ultimately affect policy outcomes [18].

Policy actors are characterized by specific capacities. Capacities refer to all resources available to a policy actor that allow the policy actor to influence the policy process and finally the policy outcome in a certain way and to a certain degree. The resources may include monetary resources, political power such as authority and discursive legitimacy, accessibility to information, and ownership of advanced technologies [19]. Policy actors are further characterized by their explicit perceptions on the substance of a policy issue and clear preferences (and preference ranking) towards solutions for the issue. These perceptions and preferences, according to the rational choice theories, may be relatively stable [20], while they may also be altered through learning and persuasion [21].

Understanding policy actors' capacities, perceptions, and preferences would allow us to infer the course of action that is likely to be chosen and thereby predict the possible policy outcomes. However, it is often the case that an actor cannot determine policy outcomes according to its perception and preference by using its own resources. It is a fact that policy actors depend on each other for resources [22]. Resource dependency theory stresses that each policy actor has to interact with others in order to acquire the necessary resources for goal achievement and survival since no actor can generate all necessary resources on its own [23].

Given resource interdependency, policy actors need to participate in one or more policy institutions. Policy institutions are sort of "platforms", "venues", or "arenas" that provide opportunities for different actors to get together, interact, and make collective decisions. Policy institutions have formal rules and informal norms that structure how policy actors make collective decisions [24]. The foremost rules of a policy institution concern about agenda-setting, because successful negotiation and cooperation requires actors to agree on a mutually attractive agenda. In determining the agenda, actors distinguish

between issues that can be put onto the agenda because they want measures on those issues during their involvement in the policy institution. Here, the issues that are considered in the agenda of the policy institution are called policy issues, which are usually collective action problems, such as water pollution, air pollution, or loss of biodiversity in a particular geographical boundary.

Other rules of policy institutions regard the structuring of membership and activities. Membership rules concern: (1) who can participate; this is a critical question because there is often a trade-off between the amount of policy actors in a policy institution and the net benefits that the policy actors may derive from participation [25]; (2) how to design role distribution; policy actors do not necessarily have to play equal roles in a policy institution, nor do they have to have equal positions in interaction [26]; and (3) the possibilities of accessing and exiting; these rules specify the conditions under which new policy actors can join an existing and ongoing interaction, and original participants may withdraw their resources and obligations from the policy institution they have participated in [27].

Rules regarding policy actors' activities within a policy institution include: (1) the use and accessibility of information, knowledge, and technology owned by the policy actors; (2) the steps and procedures that will be taken for searching alternative policy solutions and the time-frames connected with them; (3) the decision criteria for the selection of solutions and conflict regulation; and (4) the communication with the environment of the policy institution, such as the organization of the interface between the policy institution and other organizations or institutions [27,28].

Policy games are defined by the coupling of policy actors, policy institutions, and policy issues [18]. Policy games, however, are not equivalent to policy institutions. A policy game only occurs when policy actors get together in a policy institution and interact to make collective decisions over certain policy issues according to the rules of the policy institution. Collective decisions on the solution of policy issues are made from policy games. That also means a policy institution cannot operate by itself, but once policy actors participate, it is activated. Policy institutions still exist when policy actors do not participate, while policy games do not exist when policy actors do not participate in policy institutions.

Policy systems are defined as governance networks that encompass multiple interlinked policy institutions, and thus consist of multiple policy actors that may or may not be connected to one another. The boundary of a policy system is defined primarily by the policy issues at hand. Policy systems can also be defined at different scales, such as global, national, regional, local, or their mix. The choice of scale for analysis depends on the purpose of specific study [15].

2.2. Coordinative Functions in the EGF

EGF's coordinative functions originate from its structural elements of policy institutions, policy issues, and policy actors. Policy institutions play a coordinating role because the existence of multiple policy institutions in a policy system creates the potential for institutional externalities or spillovers, where actors' decisions and strategies in one institution could affect what happens in other institutions. In the EGF, two kinds of institutional externalities are distinguished: payoff externalities [15] and strategy externalities [29].

Payoff externalities occur when a decision outcome in one policy institution impacts a collective action problem in another policy institution, either in a positive or negative way. It is called a direct payoff externality if two or more policy institutions share the same policy issue; and an indirect payoff externality takes place when two policy institutions do not have overlapping jurisdiction over the same policy issue, but the decision in one institution may convey its influence to the other institution via some kind of mechanism or process [15].

Strategy externalities may occur when an actor participates in multiple policy institutions, since the behavioral strategies that an actor adopts for maximizing its utility may positively or negatively affect its achievement of utilization in other policy institutions. Scholars argue that actors participating in multiple policy institutions may generate positive strategy externalities because multiple participations may reinforce actors' reputational influence and give actors more information accessibility. Therefore, one might predict that an actor's capability and experience (through the use of strategies) to draw

resources in one policy institution may positively affect its capability to benefit from other institutions. However, there are also scholars who claim that an actor's strategies in one institution may block the actor to benefit from other institutions. The reason is that, because of bounded rationality and cognitive load constraint, actors will design strategies according to the incentive structure of an institution that may maximize its utility. However, these well-designed strategies may not match with incentive structures of other policy institutions. In other words, the "best" strategies in one policy institution might be ineffective in other policy institutions [29,30].

Apart from policy institutions that perform coordinative functions, shared policy issues under the jurisdictions of multiple policy institutions may also play a coordinating role. In the literature on collaborative governance or interorganizational relations, it is often assumed that coordination is done by direct actor interaction [31]. At the same time, it is undeniable that coordination can take place in a context where actors do not have direct interactions beforehand [32]. Particularly, Boons and Berends [33] suggest that, in the coordination of interorganizational arrangements, a lack of tight coupling between the organizations can be compensated by shared issues. In the EGF, we see a similar role for common policy issues that exist if multiple policy institutions happen to address similar problems and pay attention to similar problems (without intention). We see this emergent overlap as an important coordination mechanism between actors that are otherwise independent.

The existence of common policy issues by itself is not sufficient for multiple actors to cooperate effectively. It is also required that some actors involved in policy institutions become aware of the common issues. According to the literature on social network analysis, the recognition of the common issue is most likely to happen if there are actors that participate in more than one policy institutions. These actors usually have a bridging position in the actor network and thus play a coordinating role with information obtained from multiple institutions.

Therefore, in the EFG, coordinative functions can be performed by policy institutions, policy issues, and policy actors. Policy institutions coordinate through institutional externalities; policy issues coordinate through common ground; and policy actors coordinate through their bridging positions and more accessibility to information.

3. Materials and Methods

3.1. Case Introduction

The Guangdong-Hong Kong-Macao GBA is a national strategy of China to promote cooperation among Guangdong Province, and Hong Kong and Macao special administrative regions in various aspects such as public services, infrastructure construction, economic development, and environmental protection [34]. The GBA consists of eleven (9 + 2) cities, that is, nine mainland cities (Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing) of the Pearl River Delta (PRD) and the two special administrative regions, Hong Kong and Macao (Figure 2). It covers a total area of 560,000 km^2, and had a population of approximately 70 million at the end of 2017. The total economic size and population of the nine mainland cities account for 85% and 52% of those in Guangdong Province, respectively (see Table 1 for a summary of city facts in the GBA).

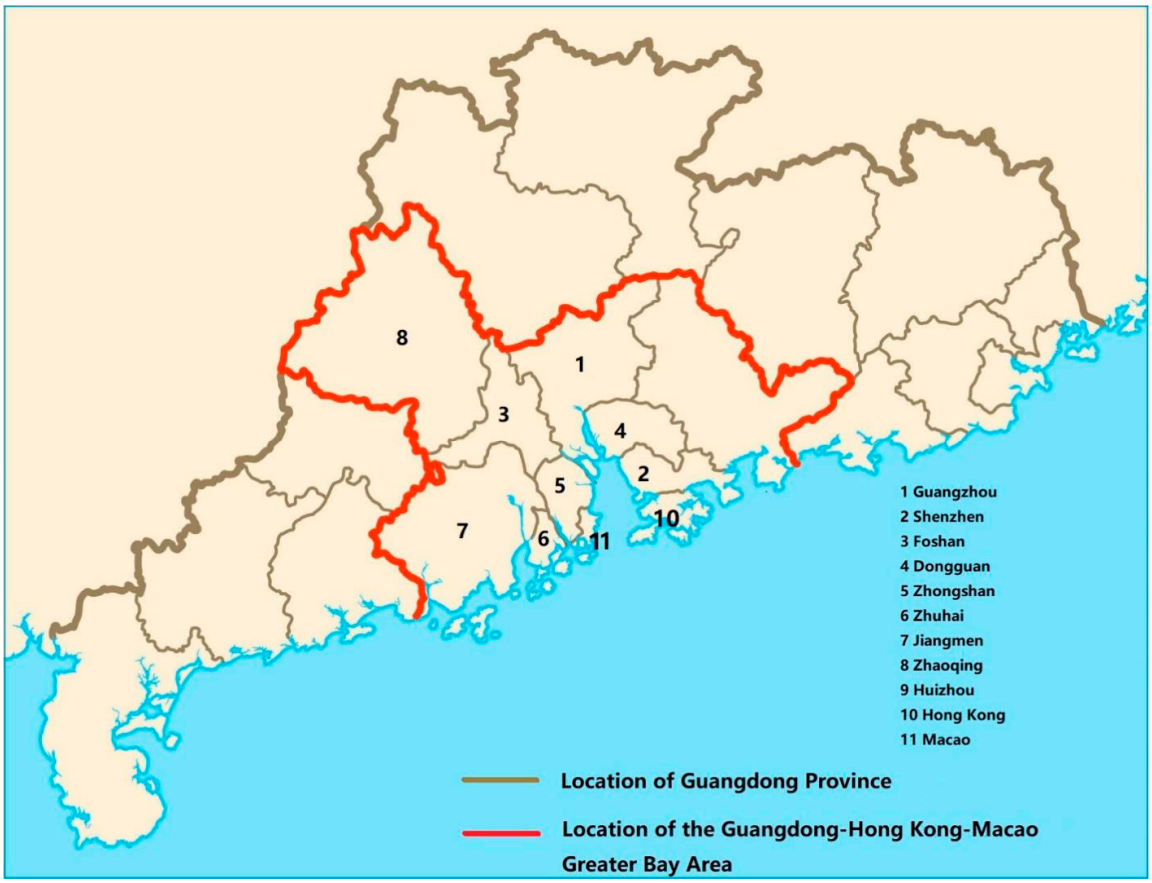

Figure 2. The Guangdong-Hong Kong-Macao Greater Bay Area (GBA).

Table 1. City facts of the Guangdong-Hong Kong-Macao GBA (adapted from Hui et al. [35]).

No.	City	Area (km^2)	GDP (Billion USD)	Population (Million)	Industrial SO_2 Emission (Thousand Ton)	Industrial Wastewater Discharge (Million Ton)
1	Guangzhou	7436	285	14	63.3	225.6
2	Shenzhen	2007	283	11.9	8.2	120.1
3	Foshan	3875	125	7.5	79.4	148.2
4	Dongguan	2512	99	8.3	112.1	234.6
5	Zhongshan	1770	46	3.2	224.9	89.1
6	Zhuhai	1696	32	1.7	226.5	55.4
7	Jiangmen	9554	35	4.5	578.6	117.5
8	Zhaoqing	15,006	30	4.1	296.5	101.5
9	Huizhou	11,159	50	4.8	300.3	83.2
10	Hong Kong	1104	319	7.4	25.3	n.a.
11	Macao	29	45	0.6	n.a.	58.6

As one of the most open and economically vibrant regions in China, the GBA plays a significant strategic role in the overall development of the country. The development of the GBA is not only a new attempt to break new ground in pursuing opening on all fronts in a new era, but also a further step in taking forward the practice of "one country, two systems". According to the estimates by the China Center for International Economic Exchanges, the total economic output of the GBA will be comparable to that of the Tokyo Bay Area by 2020; and the GBA's GDP in 2030 is expected to reach 30 trillion RMB, which will then surpass the economic size of the New York Bay Area, to become the world's largest bay area in terms of economic scale [35].

The GBA is an excellent example where officials with various backgrounds are striving very hard for regional cooperation through comprehensive and strategic planning, economic measures, environmental intervention, and institutional and legal systems of governance [36]. Nevertheless, the

cities in the GBA have different levels of economic development and different economic structures and political systems, which makes the regional cooperation a challenging task [37].

3.2. Research Design and Methods

Our study used network-based approaches and the graph theory to visualize and analyze the coordinative mechanisms for environmental governance in the GBA [38]. Based on the conceptual framework in Section 2, our analysis focused on five major questions: (1) Which actors participate in which policy institutions? (2) Which policy institutions deal with what issues? (3) What is the pattern of actor interactions, and how are they interdependent? (4) What are the direct payoff and strategy externalities between policy institutions? (5) What are the indirect payoff externalities between policy issues.

Given these questions, this study adopted two types of graph. The first type is called "two-mode network graph", which is further distinguished into "policy institution–actor network" and "policy institution–issue network". In the former network, the nodes represent either policy institutions or actors of environmental governance in the GBA (distinguished by different colors and shapes), and the edges represent which actors are involved in which policy institutions (see Figure 3a for an example). Similarly, in the latter network, the nodes represent either policy institutions or policy issues, and the edges represent which policy issues are addressed by which policy institutions (see Figure 3b for an illustration). The second type of graph is called "one-mode network graph", in which the nodes represent policy institutions (Figure 4a), actors (Figure 4b), or issues (Figure 4c), and the edges represent direct payoff and strategy externalities between policy institutions, interdependent relationships between actors, and indirect payoff externalities between policy issues correspondingly.

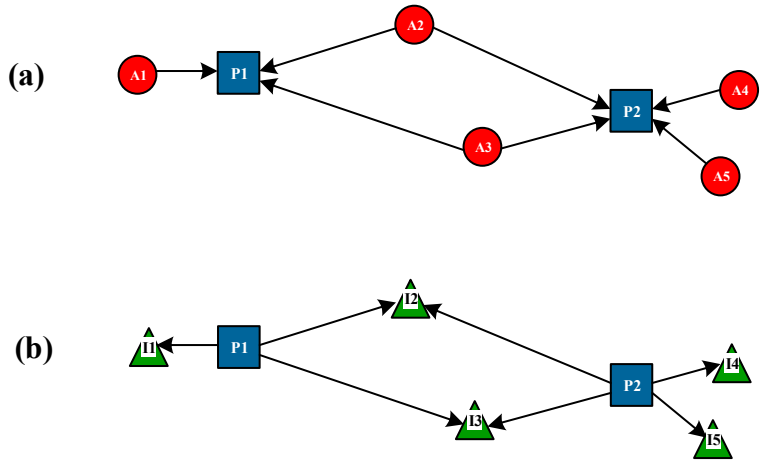

Figure 3. An illustration of the two-mode network. (**a**) Policy institution-actor network. (**b**). Policy institution-issue network.

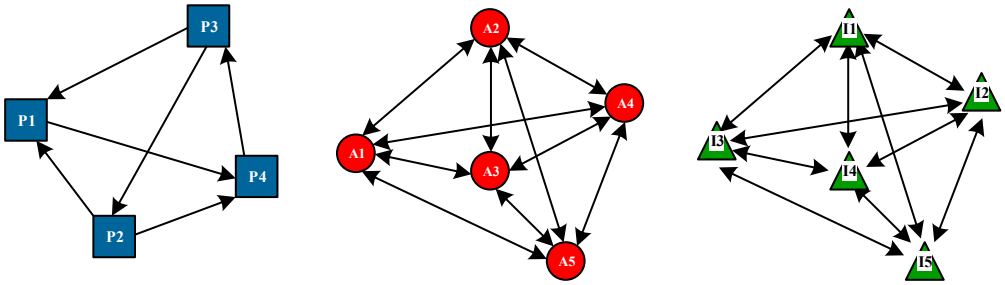

Figure 4. An illustration of the one-mode network. (**a**) Policy institution network. (**b**). Actor network. (**c**). Issue network.

We visualized the graphs by using the Ucinet software, which can help us to perform a series of analyses on the graphs. In this study, we used five indicators to reveal the coordinative mechanisms for environmental governance in the GBA (cf. [39,40]): (1) directed edge, which indicates an affiliation relationship. For example, a directed edge linking an actor to a policy institution implies that the actor participates in the policy institution; a directed edge connecting a policy institution to an issue indicates that the policy institution addresses the issue; (2) (undirected) edge, which indicates a mutual relationship between two elements. For instance, an edge between two actors indicates mutual dependence between the two actors; (3) weight of an edge, which indicates the frequency of affiliated relationship. If the weight of an edge between an actor and a policy institution is 10, that means the actor participates in 10 policy games under the policy institution; (4) two-mode betweenness centrality, which indicates the importance of a node in one mode in bridging nodes in another mode; (5) (one-mode) betweenness centrality, which indicates the central position of the node in bridging other nodes in the network. Table 2 provides a summary of our sub-questions and the approaches and indicators that are used to answer the questions.

Table 2. A summary of research questions, analytical approaches, and measurement indicators.

Research Questions	Analytical Approaches	Measurement Indicators
(1) Which actors participate in which policy institutions?	Two-mode network: policy institution–actor network	Directed edge; weight of an edge; two-mode betweenness centrality.
(2) Which policy institutions deal with what issues?	Two-mode network: policy institution–issue network	Directed edge; weight of an edge; two-mode betweenness centrality.
(3) What is the pattern of actor interactions, and how are they interdependent?	One-mode network: actor network	Undirected edge; betweenness centrality.
(4) What are the direct payoff and strategy externalities between policy institutions?	One-mode network: policy institution network	Directed edge; betweenness centrality.
(5) What are the indirect payoff externalities between policy issues?	One-mode network: issue network	Undirected edge; betweenness centrality.

3.3. Data Collection

To produce the network graphs, we need to collect and code data. The data that we used in this study are "event data". Events can be anything that occurs in a certain place during a particular interval of time. If events are launched by certain actors, the events usually carry particular purposes and are expected to arouse changes. In this study, the events we collected are collective actions that are taken by relevant actors in policy institutions to deal with regional environmental issues in the GBA. That is, an event is qualified as one piece of data in our study if the event: (1) is explicitly referred to a policy institution of the GBA; (2) involves actors from at least two cities in the GBA; and (3) aims to

address some issues of environmental governance in the GBA. The time span of the events in this study is a period of more than three decades from 1983 to 2018. The events were recorded in event sequence datasets development by Poole et al. [41] and Spekkink and Boons [32]. Each event has a time stamp calculated from the time point it occurred, a brief qualitative description of actions and interactions, the pre-conditional events for its occurrence, the actors involved, and the policy issues it deals with. The data collection process started in July 2018 and ended in January 2019. Two researchers were collecting the event data at the same time, and then synthesized the data to cross-check any missing events in individual collection. Finally, we collected 195 events that belong to 12 policy institutions. Affiliated to these events, we identified 132 actors and 76 issues associated with regional environmental governance in the GBA. The full event data are available from the corresponding author when there is a request. In the article, we provided a summary description on the groups of events in Section 4.1. The coded actors and issues can be found in the appendixes of this article.

Our sources of data include web pages, media reports, academic papers, and various types of documents produced by the actors involved in regional environmental governance in the GBA. The main webpages we searched include government portals of Guangdong, Hong Kong, and Macao, as well as other open information platforms of the involved governmental organizations. In addition, we used "baidu.com" as the main search engine to find webpages outside the governmental organizations. For media reports and academic papers, we used "CNKI.net" to collect event data. China National Knowledge Infrastructure (CNKI) contains information generated from scientific research, newspapers, conferences, and statistics yearbooks.

4. Empirical Findings

In this section, we present our empirical observations. We start with a summary description of the policy institutions in the GBA, which is built upon our event data (Section 4.1). In Sections 4.2 and 4.3, we offer analyses of the participation of actors in the policy institutions and the affiliation of policy issues with the policy institutions. In Sections 4.4–4.6, we analyze the interdependency of actors, direct payoff and strategy externalities between policy institutions, and indirect payoff externalities between policy issues, through the visualization of one-mode networks.

4.1. Introduction on the Policy Institutions in the Guangdong-Hong Kong-Macao GBA

During 1983 to 2018, twelve policy institutions were set up in the Guangdong-Hong Kong-Macao GBA. The summary descriptions on these policy institutions are shown in Table 3. Table 3 has four columns: (1) policy institution which reports the name of the policy institution; (2) label of the policy institution; (3) initial occurrence time which reports the time point (date) of the first policy game occurring in this policy institution; (4) summary description which offers a summary of the games with chronological order that have occurred in the policy institution. The summary is in the form of a qualitative description.

Table 3. Summary descriptions of policy institutions in the Guangdong-Hong Kong-Macao GBA.

Policy Institution	Label	Initial Occurrence Time	Summary Description
Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection	P1	05/01/1983	In response to the invitation of Hong Kong Environmental Protection (EP) Department, Guangdong's and Hong Kong's EP departments formally established regular communication mechanisms for mutual visits, exchanges, and notifications of EP status, especially in monitoring air and water quality. Seven years later, more governmental departments from the two places joined and built up a liaison group on EP to share and exchange EP experience and technologies. This liaison group mainly dealt with EP in the Mirs Bay Area. After ten years, the liaison group was upgraded into the Guangdong–Hong Kong liaison group on sustainable development and EP, and the EP issues have been expanded from air and water in the Mirs Bay Area to a broader range of EP issues in the whole geographical area.
Urban Planning of the Pearl River Delta	P2	26/06/1989	Nine major cities (Guangzhou, Shenzhen, Foshan, Dongguan, Zhongshan, Zhuhai, Jiangmen, Zhaoqing, and Huizhou) in Guangdong Province, i.e., the Pearl River Delta (PRD), started to think about integrated urban planning at the regional scale. This policy institution emphasizes inter-local coordination on major infrastructure layouts and promotes integrated economic development.
Joint Meeting System of Guangdong–Hong Kong Cooperation	P3	30/03/1998	This policy institution was established with the involvement of the top leaders in the two places to expand cooperation on EP between Guangdong and Hong Kong to other policy fields, including cooperation on port, infrastructure construction, urban planning, economy and trade, and public services.
Joint Meeting System of Guangdong–Macao Cooperation	P4	25/05/2001	The policy institution of high-level meeting between Guangdong's and Macao's major leaders has become the main mechanism of coordinating important affairs between Guangdong and Macao. There are several special groups addressing cooperation on economic, trade, tourism, infrastructure, transportation, and EP. A liaison group on cooperation between Guangdong and Macao has also been established as a permanent body, holding at least one plenary meeting annually in Guangdong and Macao in turn.
Closer Economic Partnership Arrangement (CEPA) between the Mainland and Hong Kong	P5	19/12/2001	The Ministry of Commerce of Mainland China and Hong Kong Financial Secretary built up this policy institution to promote closer economic and trade cooperation with special arrangements of removing administrative barriers.
Closer Economic Partnership Arrangement (CEPA) between the Mainland China and Macao	P6	20/06/2003	The Ministry of Commerce of Mainland China and Macao Economic and Financial Secretary built up this policy institution to promote closer economic and trade cooperation with special arrangements of removing administrative barriers.

Table 3. *Cont.*

Policy Institution	Label	Initial Occurrence Time	Summary Description
Pan Pearl River Delta Forum on Regional Cooperation and Development	P7	01/06/2004	This policy institution was established to promote economic cooperation, not only within the PRD, but also between the PRD and its surrounding provinces including Fujian, Hunan, Guangxi, Hainan, Sichuan, Guizhou, and Yunnan, as well as the two special administrative regions, Hong Kong and Macao.
Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection	P8	16/07/2004	This policy institution was established to promote cooperation on EP, not only within the PRD, but also between the PRD and its surrounding provinces including Fujian, Hunan, Guangxi, Hainan, Sichuan, Guizhou, and Yunnan, as well as the two special administrative regions, Hong Kong and Macao.
Macao International Environmental Cooperation Forum	P9	23/04/2008	This policy institution was established to promote transfer of experience with EP, and exhibition and exchange of EP technologies.
Hong Kong-Macao Forum on Environmental Protection	P10	06/07/2008	This policy institution was established to promote cooperation on EP between Hong Kong and Macao, and to facilitate exchange of experience and technology on EP.
Pan Pearl River Delta Joint Meeting System of Major Leaders	P11	25/07/2005	This policy institution was set up to promote communication and coordination on regional cooperation in Pan PRD at a high authoritative level between governors of provinces (Fujian, Hunan, Guangxi, Hainan, Sichuan, Guizhou, and Yunnan) in the mainland and the two chief administrators of Hong Kong and Macao.
State-led Greater Bay Area Plan	P12	03/09/2014	This policy institution was set up to facilitate the formulation of the Guangdong–Hong Kong-Macao GBA Plan. This GBA plan has been regarded as a national strategic plan to develop a globally competitive urban agglomeration.

4.2. Actor Participation in Policy Institutions

The list of actors in the Guangdong-Hong Kong-Macao GBA is shown in Appendix A of this article. In this section, we visualize part of our conceptual framework in Figure 5 (actor participation in policy institutions) and explore four questions: (1) for the actors, how many policy institutions they are active in? (2) For the policy institutions, how many actors were involved in them? (3) Which actors are the most important ones in bridging different policy institutions? (4) Which policy institutions are most critical in linking actors together?

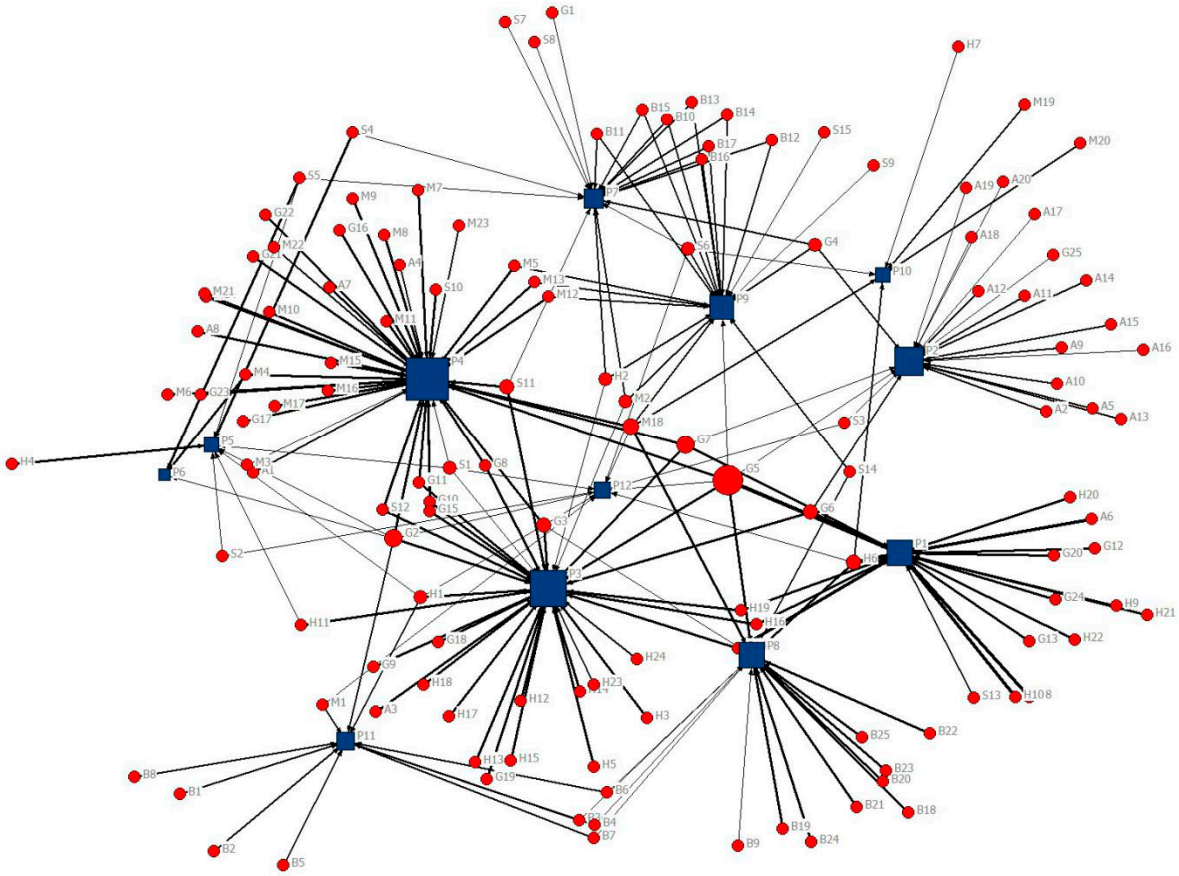

Figure 5. Actor participation in policy institutions.

Based on Figure 5, Tables 4–6 present the statistical data on actor and policy institution. We see that most actors (124 out of 132) participate in a few (1, 2, or 3) policy institutions, and only eight actors are active in four and more than four largely interdependent policy institutions (Table 4). Among the eight actors, three are from Guangdong, two are from Hong Kong, one is from Macao, and the other two are from the state. Specifically, the Guangdong Department of Ecology and Environment (G5) participates in seven policy institutions (P1, P2, P3, P4, P8, P9, and P12), and G5 is also the most active actor that plays 87 policy games under the above-mentioned policy institutions. In addition, G5 is the most central actor in linking different policy institutions (see Table 6; two-mode betweenness centrality ranks the first which is 0.248). The Guangdong Governor (G2; two-mode betweenness centrality ranks the third which is 0.081) participates in six policy institutions (P3, P4, P5, P6, P11, and P12) and plays 49 policy games in these institutions. The Macao Environmental Protection Bureau (M18, two-mode betweenness centrality ranks the third which is 0.072) participates in five policy institutions (P4, P8, P9, P10, and P12) and plays 52 games in these institutions. The Guangdong Development and Reform Commission (G7; two-mode betweenness centrality ranks the second which is 0.092) participates in four policy institutions (P1, P2, P3, and P4) and plays 55 policy games in these institutions. Particularly,

the Hong Kong Environmental Protection Department (H6; two-mode betweenness centrality ranks the fifth which is 0.039) also participates in four policy institutions (P1, P8, P10, and P12), but is the second active actor after G5, playing 60 policy games. For state-level actors, the President (S1) and the National Development and Reform Commission (S6) participate in four policy institutions, but they are not active in playing policy games, thus not included in the top 10 most central actors.

Table 4. Statistical data on actors.

	Actors	Number of participating policy institutions
Actors that are active in ≥4 policy institutions	Guangdong Department of Ecology and Environment (G5)	7
	Guangdong Governor (G2)	6
	Macao Environmental Protection Bureau (M18)	5
	Guangdong Development and Reform Commission (G7)	4
	Hong Kong Chief Executive (H1)	4
	Hong Kong Environmental Protection Department (H6)	4
	President (S1)	4
	National Development and Reform Commission (S6)	4
	Actors	Number of participating games
Top 10 actors that participate in policy games most	Guangdong Department of Ecology and Environment (G5)	87
	Hong Kong Environmental Protection Department (H6)	60
	Guangdong Department of Housing and Urban-Rural Construction (G6)	55
	Guangdong Development and Reform Commission (G7)	55
	Macao Environmental Protection Bureau (M18)	52
	Guangdong Governor (G2)	49
	Guangdong Department of Marine and Fisheries (G14)	46
	Hong Kong Transportation Department (H16)	38
	Hong Kong Constitutional and Mainland Affairs Bureau (H19)	38
	Guangdong Vice Governor (G3)	36

Table 5. Statistical data on policy institutions.

Policy Institution	Number of Total Participating Actors	Number of Actors with the Same Frequency	Frequency of Participation
P1	19	2	34
		5	26
		10	18
		2	8
P2	20	10	10
		1	8
		5	3
		3	2
		1	1
P3	33	1	21
		23	20
		2	16
		2	15
		2	13
		3	1
P4	40	1	16
		31	15
		1	12
		5	10
		1	3
		1	1
P5	8	2	19
		1	2
		5	1
P6	3	2	17
		1	1
P7	18	11	13
		7	1
P8	18	11	14
		1	13
		6	1
P9	20	16	11
		1	10
		1	5
		1	2
		1	1
P10	6	2	11
		2	10
		2	1
P11	11	11	13
P12	10	1	4
		1	3
		4	2
		4	1

Table 6. Two-mode (actor–policy institution) betweenness centralities.

	Actors	Two-mode betweenness centrality
Top 10 most central actors in bridging policy institutions	Guangdong Department of Ecology and Environment (G5)	0.248
	Guangdong Development and Reform Commission (G7)	0.092
	Guangdong Governor (G2)	0.081
	Macao Environmental Protection Bureau (M18)	0.072
	Hong Kong Transportation Department (H6)	0.039
	Guangdong Vice Governor (G3)	0.038
	State Council Hong Kong and Macao Office (S11)	0.036
	Guangdong Department of Housing and Urban-Rural Construction (G6)	0.033
	Guangdong Provincial Government (G4)	0.031
	Hong Kong Chief Executive (H1)	0.029
Ranking of importance of policy institutions in linking actors	Policy institutions	Two-mode betweenness centrality
	Joint Meeting System of Guangdong–Macao Cooperation (P4)	0.380
	Joint Meeting System of Guangdong–Hong Kong Cooperation (P3)	0.301
	Urban Planning Pearl River Delta (P2)	0.210
	Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection (P1)	0.177
	Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection (P8)	0.177
	Macao International Environmental Cooperation Forum (P9)	0.146
	Pan Pearl River Delta Forum on Regional Cooperation and Development (P7)	0.091
	Pan Pearl River Delta Joint Meeting System of Major Leaders (P11)	0.072
	Closer Economic Partnership Arrangement between the Mainland and Hong Kong (P5)	0.063
	Hong Kong-Macao Forum on Environmental Protection (P10)	0.044
	State-led Greater Bay Area Plan (P12)	0.032
	Closer Economic Partnership Arrangement between the Mainland and Macao (P6)	0.004

For the policy institutions (Table 5), we see that almost every policy institution (except P11) involves state-level actors, but these state actors play policy games relatively less often than the regional actors, usually taking a role of initiator of policy institutions or a role of mediator between various regional actors. The Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection (P1), the Joint Meeting System of Guangdong–Hong Kong Cooperation (P3), and the Closer Economic Partnership Arrangement between the Mainland and Hong Kong (P5) mainly involve bilateral actors from Guangdong and Hong Kong. The Joint Meeting System of Guangdong–Macao Cooperation (P4), the Closer Economic Partnership Arrangement between the Mainland and Macao (P6), and the Hong Kong-Macao Forum on Environmental Protection (P10) largely involve bilateral actors from Guangdong and Macao. The Urban Planning of Pearl River Delta (P2), however, only involves unilateral actors within Guangdong Province. The Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection (P8), the Macao International Environmental Cooperation Forum (P9), the Pan Pearl River Delta Joint Meeting System of Major Leaders (P11), and the state-led Greater Bay Area Plan (P12) basically involve trilateral actors from Guangdong, Hong Kong, and

Macao. In particular, the Joint Meeting System of Guangdong–Macao Cooperation (P4) involves the most (40) actors, followed by the Joint Meeting System of Guangdong–Hong Kong Cooperation (P3) that involves 33 actors.

Therefore, we conclude in this section that state-level actors usually play as facilitators to initiate policy institutions while they are not active in the policy games in later phases; it is regional actors, particularly from Guangdong, who are active in running policy institutions and bridging different policy institutions.

4.3. Issue Affiliation with Policy Institutions

The list of issues in the Guangdong-Hong Kong-Macao GBA is shown in Appendix B of this article. In this section, we visualize another part of our conceptual framework in Figure 6 (issue affiliation with policy institution) and explore three questions: (1) What is the major common ground (the most central issues) between policy institutions? (2) For the policy institutions, how many/what issues do they address? (3) Which policy institutions are most critical in linking issues together?

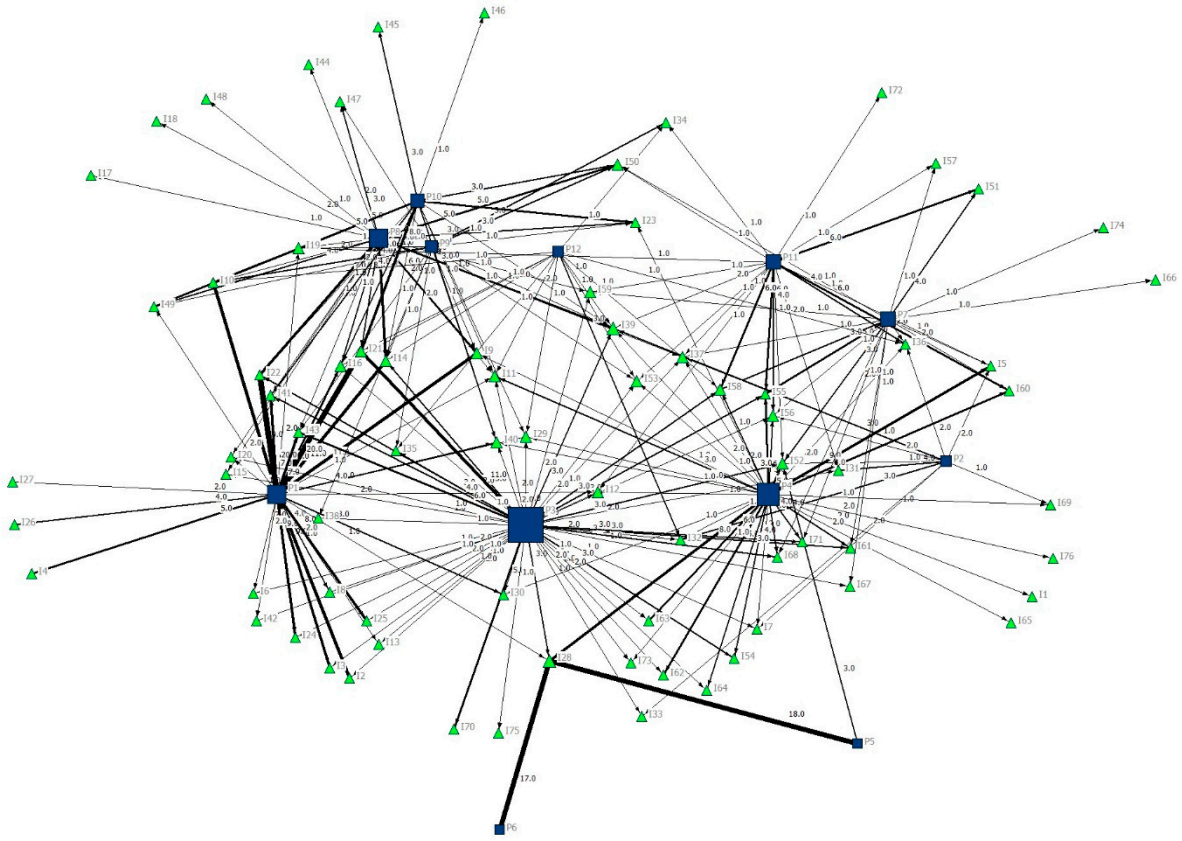

Figure 6. Issue affiliations with policy institutions.

Based on Figure 6, Tables 7–9 present the statistical data on issues and policy institutions. Examples of issues that are part of the common ground (i.e., the issues affiliated with four and more than four policy institutions) are Environmental Protection (I39) that constitutes the common ground for eight policy institutions, and Setting Common Goal (I12), Joint Monitoring (I14), Industrial Upgrading (I37), and Economy and Trade (I52) are the common grounds for six different combinations of policy institutions. The issues that make up the common grounds for five policy institutions include: Organizational Coordination (I11), Monitoring Network (I16), Air (I21), CEPA (I28), Quality Life Circle (I29), Industrial Layout (I36), Motor Vehicle Management (I40), Environmental Industry (I50), Finance (I53), Infrastructure (I56), and Energy (I58). The issues that play a role of common ground for four policy institutions consist of Hengqin Island (I5), Technology Exchange (I10), Environmental Emergency

(I19), Water (I22), Solid Waste (I23), Urban Agglomeration (I32), Total Amount Control (I41), Clean Production (I43), Environmental Education (I49), Tourism (I55), and Information Technology (I59).

Table 7. Statistical data on issues.

	Issues	Number of affiliated policy institutions
Issues that are affiliated with ≥4 policy institutions	Environmental Protection (I39)	8
	Setting Common Goal (I12), Joint Monitoring (I14), Industrial Upgrading (I37), and Economy and Trade (I52)	6
	Organizational Coordination (I11), Monitoring Network(I16), Air (I21), CEPA (I28), Quality Life Circle (I29), Industrial Layout (I36), Motor Vehicle Management (I40), Environmental Industrial (I50), Finance (I53), Infrastructure (I56), and Transportation (I58)	5
	Hengqin Island (I5), Technology Exchange (I10), Environmental Emergency (I19), Water (I22), Solid Waste (I23), Urban Agglomeration (I32), Total Amount Control (I41), Clean Production (I43), Environmental Education (I49), Tourism (I55), and Information Technology (I59)	4
Top 10 issues that are addressed in policy games most	Issues	Number of games addressing the issue
	CEPA (I28)	47
	Air (I21)	44
	Water (I22)	31
	Joint Monitoring (I14)	25
	Technology Exchange (I10)	22
	Tourism (I55)	20
	Information Sharing (I9)	19
	Environmental Protection (I39)	18
	Monitoring Network (I16)	16
	Total Amount Control (I41)	16

Table 8. Statistical data on policy institutions.

Policy Institution	Number of total Affiliated Issues	Number of Issues with the Same Frequency	Frequency of Issue Involvement
P1	56	3	11
		2	9
		1	8
		2	7
		2	6
		1	5
		3	4
		1	3
		9	2
		4	1
P2	11	4	4
		4	3
		1	2
		2	1

Table 8. *Cont.*

Policy Institution	Number of total Affiliated Issues	Number of Issues with the Same Frequency	Frequency of Issue Involvement
P3	47	1	11
		1	6
		1	5
		1	4
		10	3
		15	2
		18	1
P4	32	1	9
		1	8
		3	6
		2	5
		4	4
		4	3
		8	2
		9	1
P5	2	1	18
		1	3
P6	1	1	17
P7	18	1	5
		1	4
		2	3
		3	2
		11	1
P8	22	2	7
		1	6
		2	5
		2	4
		3	3
		4	2
		8	1
P9	15	1	4
		2	3
		2	2
		10	1
P10	15	1	8
		3	5
		2	4
		3	3
		2	2
		4	1
P11	19	4	6
		2	4
		2	2
		11	1
P12	13	1	3
		1	2
		11	1

Table 9. Two-mode (issue–policy institution) betweenness centralities.

	Label of issues	Two-mode betweenness centrality
Top 10 most central issues in bridging policy institutions	CEPA (I28)	0.042
	Environmental Protection (I39)	0.042
	Industrial Upgrading (I37)	0.030
	Economy and Trade (I52)	0.027
	Organizational Coordination (I11)	0.026
	Environmental Industry (I50)	0.021
	Joint Monitoring (I14)	0.018
	Motor Vehicle Management (I40)	0.017
	Information Technology (I59)	0.017
	Quality Life Circle (I29)	0.015
	Label of policy institutions	Two-mode betweenness centrality
Ranking of importance of policy institutions in linking issues	Joint Meeting System of Guangdong–Hong Kong Cooperation (P3)	0.409
	Joint Meeting System of Guangdong–Macao Cooperation (P4)	0.206
	Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection (P1)	0.152
	Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection (P8)	0.145
	Pan Pearl River Delta Joint Meeting System of Major Leaders (P11)	0.089
	Pan Pearl River Delta Forum on Regional Cooperation and Development (P7)	0.086
	Hong Kong–Macao Forum on Environmental Protection (P10)	0.063
	Macao International Environmental Cooperation Forum (P9)	0.039
	State-led Greater Bay Area Plan (P12)	0.026
	Urban Planning of the Pearl River Delta (P2)	0.017
	Closer Economic Partnership Arrangement between the Mainland and Hong Kong (P5)	0.000
	Closer Economic Partnership Arrangement between the Mainland and Macao (P6)	0.000

Regarding policy institutions, the Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection (P1) addresses the largest number of issues, followed by the Joint Meeting System of Guangdong–Hong Kong Cooperation (P3), the Joint Meeting System of Guangdong–Macao Cooperation (P4), and the Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection (P8) that deal with 47, 32, and 22 policy issues, respectively. Based on Table 9 that shows the two-mode centralities for issues and policy institutions, we see that these four policy institutions that address the most policy issues are simultaneously the most important institutions in linking policy issues. It implies that the connection of issues develops within policy institutions.

If we look further at Table 9, we can also find that all the most central issues in bridging policy institutions are also the issues that are affiliated with policy institutions most, that is, they are part of the common ground. In other words, the most central issues in bridging policy institutions are the issues that are typically included as central aims of the policy institutions. This includes the issues, CEPA, Environmental Protection, Industrial Upgrading, Economy and Trade, Organizational Coordination, Environmental Industry, Joint Monitory, Motor Vehicle Management, Information Technology, and

Quality Life Circle. In addition, nine out of the ten most central issues in bridging policy institutions link 8, 6, or 5 policy institutions; only one issue connects four policy institutions.

Therefore, we conclude in this section that the shared issues may play as the common ground for actors to cooperate. This indicates that actors' cooperation in policy institutions builds on issues that are central to the common ground.

4.4. Actor Interdependencies

In this section, we reconstructed the one-mode actor network for the GBA (Figure 7). Figure 5 already reveals that most actors tend to be active in only one, two, or three policy institutions, but there are some actors that are involved in four and more than four institutions and can act as bridges between the institutions because of their positions. Table 10 reports the top ten most central actors. In our case, we found that a large part of the most central actors (6 out of 10) is from Guangdong Province, one is from Macao, one is from Hong Kong, and one is from the state.

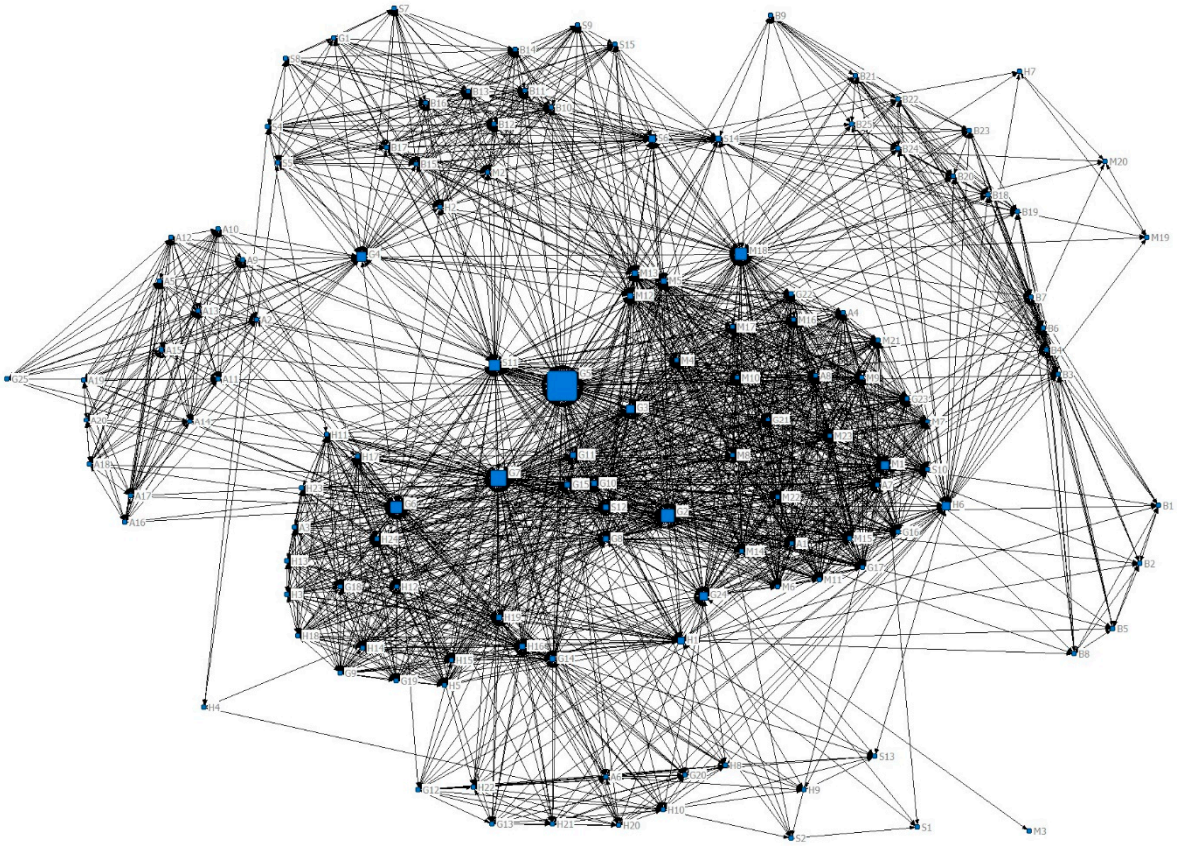

Figure 7. One-mode actor network.

Table 10. Betweenness centrality of the one-mode actor network.

Label	One-Mode betweenness Centrality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
G5	8.658	x	x	x	x				x	x			x
G7	4.022	x	x	x	x								
G2	2.921			x	x	x	x					x	x
M18	2.800				x				x	x	x		x
G6	2.434	x	x	x									
S11	2.380			x	x			x					
G4	1.628		x					x		x			
G3	1.387			x	x				x				
H6	1.331	x							x		x		x
G24	1.329	x			x								

Note: "x" means that the actor participates in the policy institution.

In addition, we found that eight out of ten most central actors are also the actors that our data report as the initiators of the policy institutions. Specifically, the Hong Kong Environmental Protection Department (H6) and Macao Environmental Protection Bureau (M18) are the two central actors initiating the most (four) policy institutions. The Guangdong Provincial Government (G4) and Guangdong Department of Ecology and Environment (G5) are the initiators of three policy institutions. However, there are some exceptions. For P5 and P6 that are CEPA for Hong Kong and Macao, respectively, their initiators are typically only loosely involved in the development of the policy institutions.

Therefore, the finding of this section confirms with the above-mentioned conclusion in Section 4.1, that is, a large part of the most central actors is from Guangdong province. This indicates that Guangdong plays a critical role in bridging different actors from Hong Kong and Macao. In addition, this section reveals that most of the central actors are the initiators of policy institutions.

4.5. Direct Payoff and Strategy Externalities of Policy Institutions

In this section, we built the one-mode policy institution network to illustrate payoff and strategy externalities in the GBA (Figure 8). We calculated the one-mode betweenness centralities of the policy institutions (Table 11). As can be seen, the Pan Pearl River Delta Forum on Regional Cooperation and Development (P7, one-mode betweenness centrality = 22.152) is the most central institution in bridging other institutions. This also means that P7 has the greatest effect on creating externalities between institutions. What follows is the State-led Greater Bay Area Plan (P12, one-mode betweenness centrality = 21.485). In addition, the Joint Meeting System of Guangdong–Hong Kong Cooperation (P3), the Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection (P8), the Pan Pearl River Delta Joint Meeting System of Major Leaders (P11), and the Joint Meeting System of Guangdong–Macao Cooperation (P4) are also institutions with positions of relatively high betweenness centralities.

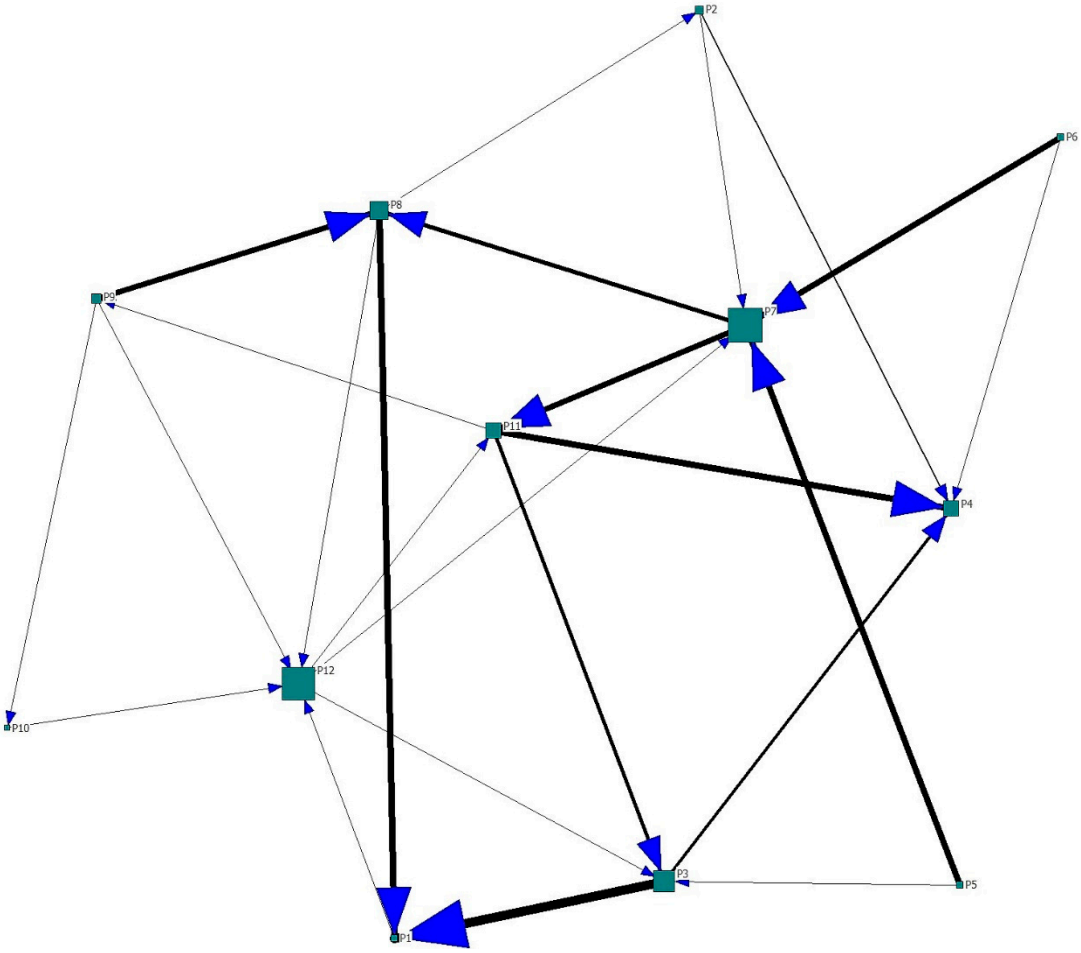

Figure 8. Externalities between policy institutions.

Table 11. Betweenness centrality of the one-mode policy institution network.

Policy Institution	One-Mode betweenness Centrality
P7	22.152
P12	21.485
P3	11.939
P8	9.606
P11	8.303
P4	7.424
P9	3.636
P2	2.424
P1	0.909
P5	0.606
P6	0.606
P10	0.000

By summing the weight of edges of the network in Figure 8, we obtained the total amount of externalities (117) between policy institutions. For example, there was a policy game that occurred in 13 January 2014, under the Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection (P1), in which Guangdong and Hong Kong planned to construct a joint monitoring network on air quality. This decision created an externality to Macao and triggered Macao to actively participate in the Guangdong and Hong Kong's plan. Later in 3 September 2014, an inter-local agreement was signed between Guangdong, Hong Kong, and Macao to jointly prevent air pollution, and Macao formally joined the construction of monitoring network for air

quality. Another example occurred between the Guangdong–Hong Kong Liaison Group on Sustainable Development and Environmental Protection (P1) and the Joint Meeting System of Guangdong–Hong Kong Cooperation (P3), where P3 created 17 externalities to P1. Although P3 comes later than P1, P3 involves discussions on a wider range of cooperation fields between Guangdong and Hong Kong, not only on environmental protection, but also on port, infrastructure, economy, and trade. Therefore, the decisions on environmental sustainability under P1 were seriously influenced by the decisions on economic cooperation in P3 since its establishment in March 1998. Moreover, externalities also happened between the Closer Economic Partnership Arrangements between the Mainland and Hong Kong and Macao (P5 and P6) and the Pan Pearl River Delta Forum on Regional Cooperation and Development (P7), where the decisions in P5 and P6 were treated as inputs for decisions in P7. Our data (1983–2018) report that P5 created 11 externalities to P7 and P6 brought about 10 externalities to P7. These externalities happened because P7 involves substantial issues on economic cooperation within the PRD, which needs to consider and incorporate decisions and plans that have been already made on economic affairs between Guangdong and Hong Kong, as well as between Guangdong and Macao. Then, the decisions of P7 subsequently created 11 externalities to P11 (the Pan Pearl River Delta Joint Meeting System of Major Leaders), because the major leaders in P11 need to facilitate the implementation of the decisions of P7 and aid with prompt coordination and communication. Furthermore, P11 brought about 12 externalities to P4 (the Joint Meeting System of Guangdong–Macao Cooperation) and 7 externalities to P3 (the Joint Meeting System of Guangdong–Hong Kong Cooperation), because the decisions of P4 and P3 must consider the pre-conditions generated by P11, i.e., the policy signals from the major leaders in the Pan PRD. Finally, another major chain of externality happened among P9, P8, and P1, where environmental technologies exhibited in P9 (the Macao International Environmental Cooperation Forum) played as inputs for decisions in P8 (the Pan Pearl River Delta Joint Meeting System of Cooperation on Environmental Protection), which then influenced the decisions in P1 for the reason that Guangdong–Hong Kong's cooperation on environmental protection has to be integrated into a higher scale of the Pan PRD.

Therefore, the above-mentioned evidence suggests that policy institutions tend to serve as an umbrella for many diverse and interdependent activities within individual institutions. Additionally, positive externalities that emerge between different policy institutions perform as important coordinators across different policy institutions.

4.6. Indirect Payoff Externalities Between Policy Issues

In this section, we reconstructed the one-mode issue network to illustrate indirect payoff externalities in the GBA (Figure 9). We calculated the one-mode betweenness centralities of the policy issues (Table 12). As can be seen, the top ten most central issues are Air, Information Sharing, Tourism, Transportation, Environmental Protection, Clean Production, Joint Monitoring, Water, Food Security, and Motor Vehicle Management. If we look back at Table 9 that shows two-mode betweenness centralities of policy issues, we will find that only Information Sharing among the top ten most central issues mentioned above shows up as one of the most important issue in linking policy institutions. This strongly indicates that many of the central issues in creating externalities are not the most central issues in bridging policy institutions. That means, indirect payoff between issues does not generate from the common ground of policy institutions. In other words, these issues do not arise because of an overarching plan, but they arise independently, as part of the plans that actors develop in different policy games. In all policy games of our data, multiple issues are connected to each other. For example, the Shenzhen Bay is often tied to the ambition of actors to control air pollution. Additionally, joint monitoring and monitoring networks often emerge with air governance. In addition, water is usually tied to different kinds of discussions, such as the Shenzhen Bay, Mirs Bay, information sharing, joint monitoring, and air. Moreover, marine resource nursing, forest wetland protection, and clean production are often tied with water and air governance. Regarding the issue of air, it is also

strongly tied with motor vehicle management and total amount control. Finally, joint monitoring and environmental education often show up together.

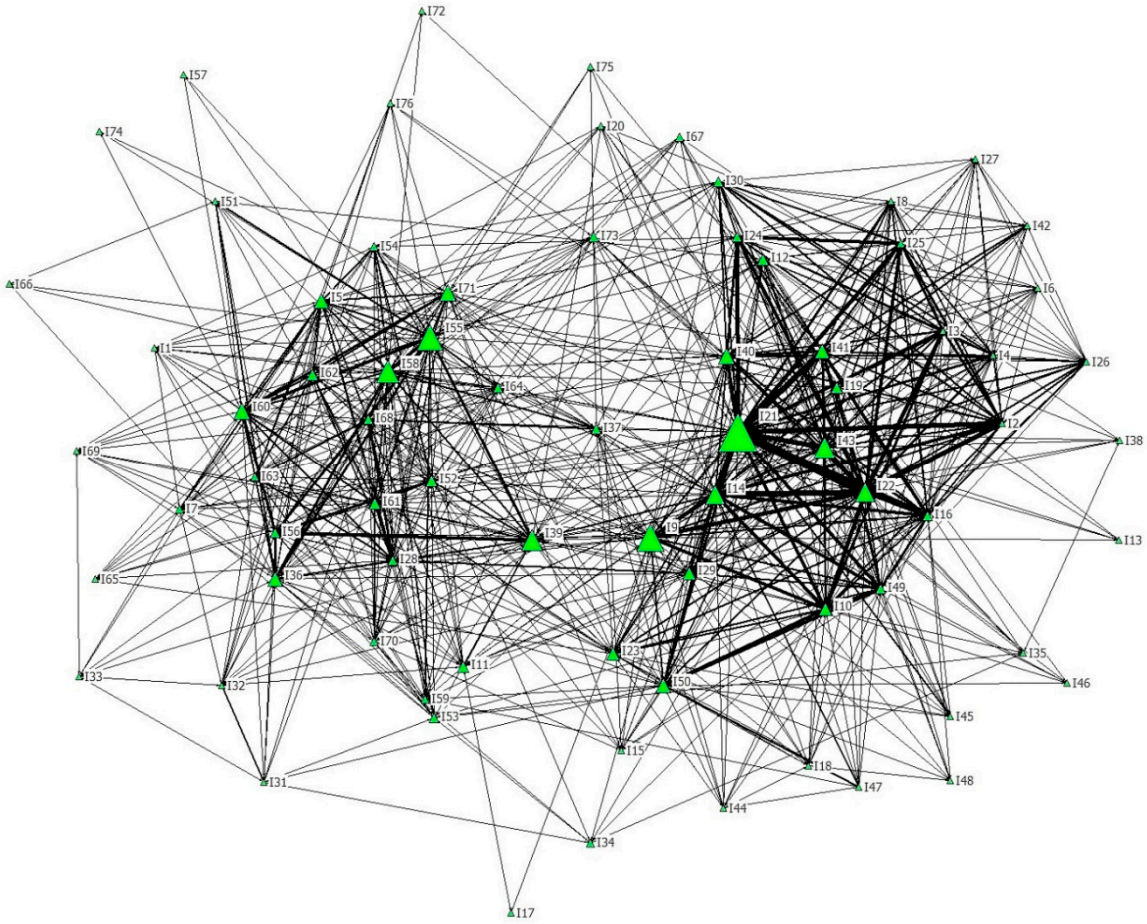

Figure 9. Externalities between policy issues.

Table 12. Betweenness centrality of the one-mode issue network.

Label	One-Mode betweenness Centrality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
I21	8.880	x		x					x		x		x
I9	5.842	x			x				x	x			
I55	5.165			x	x			x				x	
I58	4.566			x	x			x				x	x
I39	4.051		x	x	x				x	x	x	x	x
I43	3.957	x		x					x	x			
I14	3.641	x		x					x	x	x		x
I22	3.339	x		x					x		x		
I71	2.873			x	x			x					
I40	2.631	x		x	x					x	x		

Note: "x" means that the issue is addressed in the policy institution.

Therefore, we concluded from this section that, for policy issues, they emerge because they are often internally tied with each other, not because they constitute the common ground of the policy actors.

5. Conclusions

In this article, we applied the EGF to explore how regional environmental governance is coordinated across multiple interdependent policy institutions, using the case of Guangdong-Hong Kong-Macao GBA as an illustration. Our main findings include the following points.

First, policy institutions in environmental governance tend to serve as an umbrella for many diverse and interdependent activities and actors. Thus, policy institutions promote cooperation by providing interfaces that make diverse actors working together in an interacting system. From this perspective, policy institutions can serve as boundary organizations, and facilitate, enable and regulate relations between internal actors. This finding is in accordance with many empirical studies using the EGF [10–15], which recognizes that policy institutions actually perform as coordinators in decision-making among multiple actors. Apart from internal actors' coordination, our empirical evidence shows positive externalities between policy institutions. This indicates that policy institutions, through their involved actors and affiliated issues, can coordinate each other in a positive way. This finding contrasts with the existing literature on the EGF, which claims that, not only positive externalities, but also negative externalities between policy institutions may exist, that is, the incentive structure of one policy institution may influence actor decisions in other institutions in a negative way [16].

Second, regarding actors, we found that state actors and regional actors behave differently. Almost every policy institution involves state-level actors, but these state actors play policy games much less often than the regional actors, usually taking a role of facilitator to establish policy institutions or a role of mediator when conflicts emerge between regional actors. It is largely the regional actors that are active in policy games of regional environmental governance. This finding is in line with the existing literature on collaborative governance, which emphasizes the important role of leadership or higher-level authorities in facilitating and pushing forward collaborations [42–45]. In our case, among the most central regional actors, we found that a large part is from Guangdong Province and only one is from Macao and one is from Hong Kong, indicating that Guangdong possesses a larger discursive power. In addition, we found that most central actors are the actors that our data report as the initiators of the policy institutions.

Third, regarding policy issues, we found that many of the central issues in creating externalities are not the most central issues in bridging policy institutions. That means indirect payoff between issues does not generate from the common ground of policy institutions. In other words, these issues do not arise because of an overarching plan, but they arise independently, as part of the plans that actors develop in different policy games. This finding can be linked with another finding from the one-mode issue network: indirect externalities between policy issues usually happen within individual policy institutions, not across different institutions.

In this article, we focused on environmental governance in the GBA in China. Further research is required to assess the extent, to which the conceptual arguments and empirical findings presented in this article are generalizable to other regions, in other policy fields instead of environmental governance. The environmental governance cases we investigated occur largely among governmental organizations in the GBA, whereas many other regional or inter-local cooperation projects also involve non-governmental actors. Thus, it is important to assess the extent to which our findings also hold in cases of cooperation between governmental and non-governmental/private sectors.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. List of actors in the Guangdong-Hong Kong-Macao GBA.

Label	Actor Full Name
H1	Hong Kong Chief Executive
H2	Hong Kong Special Administrative Region Government
H3	Hong Kong Chief Secretary for Administration
H4	Hong Kong Financial Secretary
H5	Hong Kong Environment Bureau
H6	Hong Kong Environmental Protection Department
H7	Hong Kong Air Science Group
H8	Hong Kong Planning Department
H9	Hong Kong Development Bureau
H10	Hong Kong Agriculture Fisheries and Conservation Department
H11	Hong Kong Innovation and Technology Bureau
H12	Hong Kong Hone Affairs Bureau
H13	Hong Kong Financial Services and the Treasury Bureau
H14	Hong Kong Labor and Welfare Bureau
H15	Hong Kong Transport and Housing Bureau
H16	Hong Kong Transportation Department
H17	Hong Kong Food and Health Bureau
H18	Hong Kong Commerce and Economic Development Bureau
H19	Hong Kong Constitutional and Mainland Affairs Bureau
H20	Hong Kong Lands Department
H21	Hong Kong Water Supplies Department
H22	Hong Kong Food and Environmental Hygiene Department
H23	Hong Kong Education Bureau
H24	Hong Kong Security Bureau
G1	Guangdong Party Secretary
G2	Guangdong Governor
G3	Guangdong Vice Governor
G4	Guangdong Provincial Government
G5	Guangdong Department of Ecology and Environment
G6	Guangdong Department of Housing and Urban-Rural Construction
G7	Guangdong Development and Reform Commission
G8	Guangdong Department of Commerce
G9	Guangdong Department of Civil Affairs
G10	Guangdong Department of Science and Technology
G11	Guangdong Department of Transportation
G12	Guangdong Department of Water Conservancy

Table A1. *Cont.*

Label	Actor Full Name
G13	Guangdong Department of Forestry
G14	Guangdong Department of Marine and Fisheries
G15	Guangdong Department of Culture and Tourism
G16	Guangdong Department of Public Security
G17	Guangdong Department of Education
G18	Guangdong Health Commission
G19	Guangdong Drug Administration
G20	Guangdong Meteorological Bureau
G21	Guangdong Sports Bureau
G22	Guangdong Information Office
G23	Guangdong Traditional Chinese Medicine Bureau
G24	Guangdong Hong Kong and Macao Affairs Office
G25	Standing Committee of Guangdong Provincial People's Congress
A1	Guangzhou Mayor
A2	Guangzhou Municipal Government
A3	Guangzhou Customs District
A4	Shenzhen Mayor
A5	Shenzhen Municipal Government
A6	Shenzhen Bureau of Ecology and Environment
A7	Zhuhai Mayor
A8	Gongbei Customs
A9	Foshan Municipal Government
A10	Dongguan Municipal Government
A11	Zhongshan Municipal Government
A12	Zhuhai Municipal Government
A13	Jiangmen Municipal Government
A14	Zhaoqing Municipal Government
A15	Huizhou Municipal Government
A16	Qingyuan Municipal Government
A17	Yunfu Municipal Government
A18	Yangjiang Municipal Government
A19	Shanwei Municipal Government
A20	Heyuan Municipal Government
M1	Macao Chief Executive
M2	Macao Special Administrative Region Government
M3	Macao Chief Executive Office
M4	Macao Economic and Financial Secretary
M5	Macao Economic Bureau

Table A1. *Cont.*

Label	Actor Full Name
M6	Macao Fire Bureau
M7	Macao News Bureau
M8	Macao Culture Bureau
M9	Macao Health Bureau
M10	Macao Sports Bureau
M11	Macao Education and Youth Affairs Bureau
M12	Macao Trade and Investment Promotion Institute
M13	Macao Tourist Office
M14	Macao Land, Public Work and Transport Bureau
M15	Macao Science and Technology Commission
M16	Macao Customs
M17	Macao Security Department
M18	Macao Environmental Protection Bureau
M19	Macao Maritime and Water Bureau
M20	Macao Geophysical and Meteorological Bureau
M21	Macao Energy Development Office
M22	Macao Transport Bureau
M23	Macao Construction and Development Office
B1	Fujian Governor
B2	Jiangxi Governor
B3	Hunan Governor
B4	Guangxi Governor
B5	Hainan Governor
B6	Sichuan Governor
B7	Guizhou Governor
B8	Yunnan Governor
B9	Yunnan Vice Governor
B10	Fujian Provincial Government
B11	Jiangxi Provincial Government
B12	Hunan Provincial Government
B13	Guangxi Provincial Government
B14	Hainan Provincial Government
B15	Sichuan Provincial Government
B16	Guizhou Provincial Government
B17	Yunnan Provincial Government
B18	Fujian Department of Ecology and Environment
B19	Jiangxi Department of Ecology and Environment
B20	Hunan Department of Ecology and Environment
B21	Guangxi Department of Ecology and Environment
B22	Hainan Department of Ecology and Environment

Table A1. *Cont.*

Label	Actor Full Name
B23	Sichuan Department of Ecology and Environment
B24	Guizhou Department of Ecology and Environment
B25	Yunnan Department of Ecology and Environment
S1	President
S2	Premier
S3	State Council
S4	State Council Development Research Center
S5	Ministry of Commerce
S6	National Development and Reform Commission
S7	Ministry of Transport
S8	Ministry of Culture and Tourism
S9	Ministry of Industry and Information Technology
S10	General Administration of Customs
S11	State Council Hong Kong and Macao Office
S12	State Council Liaison Office in Hong Kong
S13	South China Sea Branch State Ocean Administration
S14	Ministry of Ecology and Environment
S15	Ministry of Science and Technology

Appendix B

Table A2. List of policy issues in the Guangdong-Hong Kong-Macao GBA.

Label	Policy Issue
I1	Cuiheng New Area
I2	Shenzhen Bay
I3	Mirs Bay
I4	Fast River
I5	Hengqin Island
I6	Pearl River Estuary
I7	Nansha New Area
I8	Information disclosure
I9	Information sharing
I10	Technology exchange
I11	Organizational coordination
I12	Setting common goal
I13	Formulating common plan
I14	Joint monitoring
I15	Joint enforcement
I16	Monitoring network

Table A2. *Cont.*

Label	Policy Issue
I17	Division of responsibilities
I18	Pollution dispute settlement
I19	Environmental emergency
I20	Pollution warning
I21	Air
I22	Water
I23	Solid waste
I24	Marine resources nursing
I25	Forest wetland protection
I26	Wildlife conservation
I27	Marine fish protection
I28	CEPA
I29	Quality life circle
I30	Urban planning
I31	Urban system planning
I32	Urban agglomeration
I33	Urban-rural integration
I34	Low-carbon city
I35	Circular economy
I36	Industrial layout
I37	Industrial upgrading
I38	Collaboration industry-University-Research Institute
I39	Environmental protection
I40	Motor vehicle management
I41	Total amount control
I42	Emission trading
I43	Clean production
I44	Ecological compensation
I45	Environmental impact assessment
I46	Environmentally friendly procurement
I47	Environmental protection research
I48	Public participation
I49	Environmental education
I50	Environmental industry
I51	Regional cooperation
I52	Economy and trade
I53	Finance
I54	Port
I55	Tourism

Table A2. *Cont.*

Label	Policy Issue
I56	Infrastructure
I57	Energy
I58	Transportation
I59	Information technology
I60	Social livelihood
I61	Education
I62	Medical care
I63	Medicine
I64	Culture
I65	Fire control
I66	Media
I67	Agriculture
I68	Modern service
I69	Fundamental public service
I70	Property right
I71	Food security
I72	Irrigation works
I73	Maritime search and rescue
I74	Credit system
I75	Weather forecast
I76	Youth innovation and entrepreneurship

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