Article

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

Received: 15 May 2019; Accepted: 30 May 2019; Published: 3 June 2019

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 seemingly 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 km², 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).
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](image-url)

**Figure 3.** An illustration of the two-mode network. (a) Policy institution-actor network. (b). Policy institution-issue network.
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.                                                                                                                                 |
| 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 |
|-------------------------------------------------------------|---------------------------------------------|
| 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               |
|-------------------------------------------------------------|---------------------------------------------|
| 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                                          |
| 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                         |
|                    |                                      | 10                                     | 10                        |
|                    |                                      | 1                                      | 8                         |
|                    |                                      | 5                                      | 3                         |
|                    |                                      | 3                                      | 2                         |
|                    |                                      | 1                                      | 1                         |
| P2                 | 20                                   | 1                                      | 21                        |
|                    |                                      | 23                                     | 20                        |
|                    |                                      | 2                                      | 16                        |
|                    |                                      | 2                                      | 15                        |
|                    |                                      | 2                                      | 13                        |
|                    |                                      | 3                                      | 1                         |
| P3                 | 33                                   | 1                                      | 16                        |
|                    |                                      | 31                                     | 15                        |
|                    |                                      | 1                                      | 12                        |
|                    |                                      | 5                                      | 10                        |
|                    |                                      | 1                                      | 3                         |
|                    |                                      | 1                                      | 1                         |
| P4                 | 40                                   | 2                                      | 19                        |
|                    |                                      | 1                                      | 2                         |
|                    |                                      | 5                                      | 1                         |
| P5                 | 8                                    | 2                                      | 17                        |
|                    |                                      | 1                                      | 1                         |
| P6                 | 3                                    | 2                                      | 13                        |
|                    |                                      | 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.

| Top 10 most central actors in bridging policy institutions | Two-mode betweenness centrality |
|-----------------------------------------------------------|--------------------------------|
| 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 | 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.](image-url)

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).
(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 |
|------------------------------------------------------------------------|------------------------------------------|
| 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                                        |

### 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                                        | 17                            |
|                    |                                  | 2                                        | 11                            |
|                    |                                  | 1                                        | 9                             |
|                    |                                  | 2                                        | 8                             |
|                    |                                  | 1                                        | 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.

| Top 10 most central issues in bridging policy institutions | Label of issues | Two-mode betweenness centrality |
|-----------------------------------------------------------|-----------------|---------------------------------|
| 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           |

| Ranking of importance of policy institutions in linking issues | Label of policy institutions | Two-mode betweenness centrality |
|----------------------------------------------------------------|-------------------------------|---------------------------------|
| 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  | x  | x  |
| M18   | 2.800                           | x  | x  | 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  | x  |
| G24   | 1.329                           | x  | x  | 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.
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 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.

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.
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.

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/private sectors. 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.

Author Contributions: W.Z. and R.M. contributed evenly to the entire article.

Funding: This research was funded by the Fundamental Research Funds of Central Universities (grant number: DUT18RW218); the Research Foundation Project of International Education College of Dalian University of Technology (grant number: SIE18RZD3); Dalian University of Technology 2018 Teaching Reform Project (grant numbers: ZL201852 and JG201809); the National Natural Science Foundation of China (grant number: 71774022); Liaoning Revitalization Talents Program (grant number: XLYC1807057).

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 Home 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 |
| 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 |

### References

1. Hartley, K. Environmental resilience and intergovernmental collaboration in the Pearl River Delta. *Int. J. Water Resour. Dev.* 2017, 34, 525–546. [CrossRef]
2. Hou, X.; Chan, C.K.; Dong, G.H.; Yim, S.H.L. Impacts of transboundary air pollution and local emissions on PM2.5 pollution in the Pearl River Delta region of China and the public health, and the policy implications. *Environ. Res. Lett.* 2019, 14, 034005. [CrossRef]
3. Liu, B.; Peng, S.; Liao, Y.; Long, W. The causes and impacts of water resources crises in the Pearl River Delta. *J. Clean. Prod.* 2018, 177, 413–425. [CrossRef]
4. Lee, Y.F. Tackling cross-border environmental problems in Hong Kong: Initial responses and institutional constraints. *China Q.* 2002, 172, 986–1009. [CrossRef]
5. Yeh, A.; Xu, J. *China’s Pan Pearl River Delta: Regional Cooperation and Development*; Hong Kong University Press: Hong Kong, China, 2011.
6. Xu, J.; Yeh, A. *Governance and Planning of Mega-City Regions: An International Comparative Perspective*; Routledge: Oxon, UK, 2010.
7. Xu, J. Governing city regions in China: Theoretical discourses and perspectives for regional strategic planning. *Town Plan. Rev.* 2008, 79, 157–185. [CrossRef]
8. Yang, C. Multilevel governance in the cross-boundary region of Hong Kong-Pearl River Delta, China. *Environ. Plan. A* 2005, 37, 2147–2168. [CrossRef]
9. Yang, C. The geopolitics of cross-boundary governance in the Greater Pearl River Delta, China: A case study of the proposed Hong Kong-Zhuhai-Macao Bridge. *Political Geogr.* 2006, 25, 817–835. [CrossRef]
10. Garcia, M.M.; Bodin, O. Participation in multiple decision-making water governance forums in brazil enhances actors’ perceived level of influence. *Policy Stud. J.* 2018, 47, 27–51. [CrossRef]
11. Scott, T.A.; Greer, R.A. Polycentricity and the hollow state: Exploring shared personnel as a source of connectivity in fragmented urban systems. Policy Stud. J. 2018, 47, 52–76. [CrossRef]
12. Fischer, M.; Maag, S. What are cross-sectoral forums important to actors? Forum contributions to cooperation, learning and resource distribution. Policy Stud. J. 2019, 47, 114–137. [CrossRef]
13. Long, N.E. The local community as an ecology of games. Am. J. Sociol. 1958, 64, 251–261. [CrossRef]
14. Berardo, R.; Lubell, M. The ecology of games as a theory of polycentricity: Recent advances and future challenges. Policy Stud. J. 2019, 47, 6–26. [CrossRef]
15. Lubell, M. Governing institutional complexity: The ecology of games framework. Policy Stud. J. 2013, 41, 537–559. [CrossRef]
16. Lubell, M.; Henry, A.D.; McCoy, M. Collaborative institutions in an ecology of games. Am. J. Political Sci. 2010, 54, 287–300. [CrossRef]
17. Contractor, N.S.; Wasserman, S.; Faust, K. Testing multitheoretical, multilevel hypotheses about organizational networks: An analytic framework and empirical example. Acad. Manag. Rev. 2006, 31, 681–703. [CrossRef]
18. Ostrom, E. Governing the Commons; Cambridge University Press: Cambridge, UK, 1990.
19. Ansell, C.; Gash, A. Collaborative platforms as a governance strategy. J. Public Adm. Res. Theory 2018, 28, 16–32. [CrossRef]
20. Spekkink, W.A.H.; Boons, F.A.A. The emergence of collaborations. J. Public Adm. Res. Theory 2016, 26, 613–630. [CrossRef]
39. Mu, R.; Spekkink, W. A running start or a clean slate? How a history of cooperation affects the ability of cities to cooperate on environmental governance. *Sustainability* 2018, 10, 1950. [CrossRef]

40. Mu, R. Role of law, position of actor and linkage of policy in China’s national environmental governance system, 1972–2016. *Sustainability* 2018, 10, 1065. [CrossRef]

41. Poole, M.S.; van de Ven, A.H.; Dooley, K.; Holmes, M.E. *Organizational Change and Innovation Processes: Theory and Methods for Research*; Oxford University Press: New York, NY, USA, 2000.

42. Ansell, C.; Gash, A. Collaborative governance in theory and practice. *J. Public Adm. Res. Theory* 2008, 18, 543–571. [CrossRef]

43. Daley, D.M. Interdisciplinary problems and agency boundaries: Exploring effective cross-agency collaboration. *J. Public Adm. Res. Theory* 2009, 19, 477–493. [CrossRef]

44. Bryson, J.M.; Crosby, B.C.; Stone, M.M. The design and implementation of cross-sector collaborations: Propositions from the literature. *Public Adm. Rev.* 2006, 66 (Suppl. 1), 44–55. [CrossRef]

45. Mu, R.; de Jong, M.; Koppenjan, J. Assessing and explaining interagency collaboration performance: A comparative case study of local governments in China. *Public Manag. Rev.* 2019, 21, 581–605. [CrossRef]

© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).