Interregional collaboration for food safety governance: The scheme design and performance evaluation with cases in China

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Abstract: The spatial spillover of food safety risks and the regional mobility of food enterprises make territorial governance inefficient, which calls for interregional collaboration to enhance food safety in the context of territorial governance. However, due to the lack of a collaborative food safety governance scheme, there has been no substantial progress in interregional collaboration for food safety governance in China. Therefore, this paper refines the three key elements of food safety collaboration from the perspective of supply chain, economy and geography and puts forward the optimal zoning scheme of interregional collaboration for food safety governance. By analysing the evolution trend of interregional collaboration, we found China has already produced the germination of interregional collaboration in terms of food safety issues, though it has been slow and volatile. To promote the process of interregional collaboration, this paper also analyses the determinants of the coordinated regulatory performance of food safety. The results show that collaborative actions within regions can facilitate coordinated regulatory practice. The interregional difference in regulatory intensity and

consumption patterns hinder the interregional collaboration for food safety governance, while the interregional difference in industrial structure inversely promotes the coordinated regulatory performance. These findings lend support to effective promotion of interregional collaboration.

1 Introduction

Food safety is one of the major concerns of consumers, especially in developing countries (Zhllima et al., 2015). As food is public goods as characterised by externalities and information asymmetry, the government is responsible for ensuring the service delivery of food safety governance (Broughton and Walker, 2010; Yang et al., 2022); however, their regulatory enforcement is often inefficient, which has led to increasing numbers of food scandals. Food safety risks, for example, microbial contamination, chemical contamination, food adulteration, misuse of food additives, environmental contaminants, illegal non-food substances and mislabelling, are all important factors that lead to the outbreak of food safety incidents. In the context of e-commerce and urban agglomeration, the cross-regional distribution of food further increases the possibility of risk spillover. Take Shanghai in China for example; the production of cereal, vegetable, fruit, meat and aquatic products decreased 14.5%, 26.4%, 21.8%, 46.8% and 13.6% in 2019 respectively from 2015. The demand for food not only increases the probability of cross regional transactions in food production, circulation

and consumption, but also strengthens the spatial spillover of food safety risks. In such cases, researchers have raised concerns about interregional collaboration for food safety governance, which mostly focuses on theoretical evidence of influential factors, elaboration, or cases in developed countries (Ansell and Gash, 2007; Gerber et al., 2013; Hale and Bartlett, 2019; Liu et al., 2022; Thomson and Perry, 2006; Wang and Zhang, 2019). Specifically, food safety governance specifies the activities and processes in which stakeholders such as government, market, and society actors adopt at either single, multi-agent or interregional levels to realise food safety. As one of the important models for efficient governance that has prevailed newly in recent years, interregional collaboration is a new form of partnership between stakeholders in different regions, specifically different local authorities, in charge of food safety, characterised as equality, exchange, cooperation, negotiation, coordination and collaboration. These in turn generate interaction, mutual assistance, mutual benefits, shared governance, and win-win outcomes during the process of alleviating food safety risks (European Commission, 2018). Many studies provide theoretical evidence that collaboration among local governments and agencies enables the more effective governance of food safety than what might be achieved by these authorities alone (Abdi and Aulakh, 2017; Buckley, 2015; Li et al., 2016). However, interregional collaboration seems to be difficult to promote in developing countries because of their relatively weak institutional frameworks (Imami et al., 2021), and this problem tends to be more notable in China where the state carries regulatory responsibility but lacks the capacity to effectively enforce regulations in the enormous geographical area and the extensive

distribution and fragmentation of food production.

Considering the difficulty in assessing and tracking the responsible entities from a quality and safety standpoint, the involvement of food safety in the performance appraisal system weakens the pursuit of economic development for competitive and fragmented local authorities in China. A heterogeneous level of economic development also leads to differentiated motivations for food safety regulation, increasing the difficulty in interregional collaboration (Wang, 2020; Xie et al., 2018; Yang and Chen, 2008; Yang et al., 2022). On the other hand, negotiation costs generally increase with the collective scale. Interregional collaboration for food safety governance should thus be controlled within a reasonable scale to improve collaborative efficiency (Feiock and Scholz, 2010; Hu et al., 2019). Although China has promoted interregional collaboration for food safety governance in some pilot schemes, such as Beijing-Tianjin-Hebei (2016), Yangtze River Delta (2019), and the Greater Bay Area (2021), and has formulated corresponding initiatives to refine and deepen cooperation, most regions in China still lack a relatively effective interregional collaboration system. There are also the lack of formal initiatives in China to prevent local authorities being caught in a collective action dilemma to be a free rider. Therefore, this paper focuses on the governance structure in China to explore reasonable strategies for partnership selection and interregional collaboration.

Unlike environmental pollution, the spillover of food safety risks is more hidden since most of the illegal additives can only be discovered after laboratory testing; however, it receives less attention in academic studies. Given food safety is a public

health issue which is characterised by a high degree of complexity, externality, uncertainty and unobservability, the chain reaction caused by the outbreak of food safety crises will be much higher than that in other industries (Noto et al., 2020; Yang et al., 2021). With the development of e-commerce, the growing social distance between producers and consumers, which leads to delocalisation of food supply chains, will further amplify food safety risks and the corresponding adverse effects (Garnett and Wilkes, 2014; Yasuda, 2017). In such cases, food safety violations may show obvious geographical concentration and spatial correlation, which calls for urgent collaboration and interaction among stakeholders in different regions to reach the common goal – food safety for all citizens (Devaney, 2016; Chu and Wang, 2018; Lee et al., 2019). Some studies have highlighted the importance of interregional collaboration in the field of food safety governance. For example, Donkers (2013) classified the food system into six tiers and discussed the appropriate process to achieve multi-level governance. The study envisages that the realisation of government cooperation in food systems should start from a lower level such as a short chain between producers and consumers, and progress to a higher level such as states or international markets. Based on a case study in Michigan, Buckley (2015) found that collaborative and assistive actions of government officials can promote compliance behaviours among producers. Based on the spatial heterogeneities and correlations found in the cluster analysis of food safety incidents, Li et al. (2016) suggested interregional collaboration and a risk warning system are effective channels to cope with the geographical externalities of food safety risks. Hale and Bartlett (2019)

introduced the collaboration case between the Canadian Food Inspection Agency and the U.S. Food and Drug Administration to underline that efficient coordination among food safety regulatory bodies can not only help improve food quality, but also prevent huge economic losses caused by food safety incidents. The interregional collaboration for food safety governance is thus critical to enhancing social welfare.

With regard to influential factors that may affect interregional collaboration, there are many studies that have already discussed relatively comprehensive indicators, for example, the relevant attributes of collaborative participants, such as the competencies and resources they possess (Kumar and Banerjee, 2014; LeRoux and Carr, 2007; Sousa, 2013), their political structures (Benson et al., 2013; Boschma, 2005; Feiock, 2013; Sabatier et al., 2005), and their interdependence with other regions (Börzel, 2016; Feiock, 2007; Ha et al., 2011; Sabatier et al., 2005). Specifically in the interrelations across regions, cooperation among regions with direct interdependence on food supply not only helps coordinate regulatory resources, but also ensures the transparent exchange of complementary information, thus further lowering the barriers of accountability and accelerating the response speed to risks (Chen et al., 2013; Datta and Christopher, 2011; Leat and Revoredo-Giha, 2013; Li et al., 2012a). Indirect interdependence – for example, close economic ties and geographical proximity – can also help regulators forge interregional collaboration by sharing similar preferences in products and promoting equality in bargaining positions (Chen, 2020; Feiock, 2013; Feiock et al., 2009; Gerber et al., 2013; McPherson et al., 2001; Segura and Fraga, 2008; Wang et al., 2019).

All in all, the reality of food safety risks spillover along supply chains calls for interregional collaboration among stakeholders, especially for local authorities. Although the theories and practice of interregional collaboration have been widely studied, the studies mainly focus on either theoretical elaboration or case studies between two specific regions or organizations, but they fall short of quantitatively exploring the mechanisms and their impacts on the performance of the food safety regulatory collaboration in the context of interregional spreading of food risks and trust crises.

Therefore, two research questions are posed to fill these research gaps:

1. How does one identify and select appropriate partners to design appropriate collaborative schemes among local authorities?

2. How do interregional collaborative practices and other factors work for the coordinated regulatory performance of food safety based on collaborative schemes?

Clustering existing governance regions for collaboration can be considered as the outcome of optimal food safety governance given that the transaction costs are minimised. In this article, we attempt to address the above two research questions via theoretical discussion, counterfactual analysis and empirical analysis. Given that the central authority in China plays a significant role in policy guidance and macro control over local authorities, its role in facilitating collaboration is more important in vertical structures rather than in horizontal ones.[1] Since we are trying to discover the effective

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[1] Zhang et al. (2012) demonstrate that the structure of food safety regulation can be divided into three types: vertical collaboration (e.g. collaboration between central and local authorities), horizontal collaboration (e.g. collaboration among local authorities), and cross-agency collaboration (e.g.

mechanism of choosing partners to cooperate in food safety governance, we focus on horizontal collaborative actions among regional regulatory departments in this paper. Specifically, we first identify and select appropriate collaborative partners from the perspective of supply chain, economy and geography to design a scheme for optimal interregional collaboration. Then we estimate the evolution trend and validity with counterfactual analysis and find regions clustered in the designed scheme that have already produced the germination of interregional collaboration in terms of food safety governance, though slow and volatile. Finally, to promote the process and performance of interregional collaboration, empirical analysis is used to analyse the determinants of the coordinated regulatory performance of food safety.

Therefore, this paper has four contributions. First, this paper challenges the status quo of interregional collaboration research, which mainly focuses on the field of economic development, environment, and healthcare networks (Krueger, 2005; Daley, 2008; Martin-Misener et al., 2012; Bolumole et al., 2015), but little research has taken place from food safety perspectives, which are also suffering from spillover effects among regions. Second, to overcome inherent bargaining and collective action issues, this research fills the gap in interregional collaboration by designing a collaborative scheme for food safety governance. In comparison to the existing literature, which focuses on cases of interregional authorities that have already established collaborative relationships, this article not only innovatively identifies regions that require

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collaboration among local authorities, enterprises, non-governmental organizations, the media, and the public).

interregional collaboration for food safety governance, but it also gives insight into the mechanism for selecting appropriate collaborative partners. Third, while the existing literature discusses interregional collaboration for food safety issues mostly on theoretical elaboration or case studies, we analyse the evolution trend, driving force and determinants of the interregional collaboration with counterfactual and empirical analysis to investigate the coordinated regulatory performance. Finally, our research also provides some important managerial guidance and implications that are useful for governments in charge of food safety governance to promote coordinated development across regions.

The remainder of this paper is organised as follows: Section 2 introduces the theoretical framework of this paper, which puts forward two clustering schemes under different scenarios for interregional collaboration. Section 3 provides a description of the empirical strategy and relevant data. Section 4 estimates the effects of interregional collaboration among presumptive zoning schemes and other determinants on the regulatory performance of food safety. Finally, in Section 5, we present key findings and discuss implications and suggestions for governments.

2 Theoretical framework

2.1 Collaborative mechanisms for selecting collaborative partners in food safety governance

Interregional collaboration for food safety governance denotes a new form of partnership among different local authorities in charge of food safety. It is one kind of

collective action which aims at setting and achieving common goals of realising interaction, mutual assistance, mutual benefits, shared governance, and win-win outcomes during the process of alleviating food safety risks. Specifically, this kind of collaboration among different local governments includes deliberation, negotiation, and agreement of the common goal of food safety improvement (which is defined as coordination), the implementation of the common goal (which is defined as cooperation), and also the voluntary behaviours which help other partners achieve goals (Castañer and Oliveira, 2020). Relevant actions in interregional collaboration conform to the six determinants of collective behaviours mentioned in Smelser's original formulation (Smelser, 1962), that is, structural conduciveness (the reality that collaborative governance is better than territorial governance when considering the spatial spillover and externalities of food safety issues), structural strain (continuous occurrence of food violations), growth and spread of a generalized belief (increasing the consumer's demand for food quality and safety), precipitating factors (the outbreaks of food safety incidents such as the melamine incident), mobilization of participants for action (the emergence and promotion of a co-governance model), and the operation of social control (relevant regulations and standards of territorial governance). Under these collective actions, the scale of the collective will definitely affect the efficiency of the collaborative collective.

For interregional collaboration for food safety governance, the expansion of collective scale not only increases the negotiation cost and uncertainty, but also increases the possibility of free-riding, resulting in the weakening of the efficiency of

collective actions (Olson, 1971; Feiock and Scholz, 2010; Hu et al., 2019). Although the government has incorporated food safety into local performance appraisal since 2012 (General Office of the State Council, 2012), it is affected by different levels of economic development, governance priorities, and regulatory resources, therefore there are great differences in the motivation of food safety governance among local governments. For example, in well-developed provinces, consumers tend to pursue high-quality consumption of food, which necessitates stringent food safety regulation of governments. In such cases, governments tend to invest more into food safety issues. Whereas in less-developed provinces, governments generally give priority to economic development rather than service delivery, and they are thus more likely to reduce food safety expenditures and share the regulatory results of other regions. In such cases, collaborations among different local governments can easily give rise to the inequality of rights, liabilities, and profit and further trigger negative incentives to interregional collaboration (Unnevehr, 2007; Wong, 2022; Xie et al., 2018). Large-scale interregional collaboration might in turn reduce the efficiency of food safety governance. Therefore, interregional collaboration for food safety issues should be controlled within a reasonable scope.

Although collective action theory does not specify the mechanism for determining the optimal collective scale, Buchanan and Tullock (1965) believed that whether individuals attend social activities within the collective scope depends on the degree of social interdependence. On one hand, territorial governance of food safety in different provinces along the supply chain are hard to deal with in relation to the spatial spillover

of food safety risks. The complementarity among provinces based on the relationship of food supply emphasises the necessity of interregional collaboration for food safety governance. On the other hand, the externality of food safety risks generally spills over to provinces with similar consumption structure or provinces with geographical proximity, which also emphasises the necessity of interregional collaboration. Therefore, this paper explores the collaborative mechanism of interregional collaboration for food safety governance following the social interdependence viewpoint of Buchanan and Tullock (1965). In other words, this paper believes interregional collaboration for food safety governance depends on the social networks that provinces are involved in. This social interdependence refers to not only to the degree of provincial closeness along the food supply chain with complementary characteristics, but also to the economic and geographical ties among provinces with external characteristics. Specifically, there are three elements that can reflect either direct or indirect social interdependence among provinces that may affect interregional collaboration: transaction frequency, economic development, and geographical proximity.

2.1.1 Dependence on food supply relationships

Provinces with close food supply relationships are more motivated to cooperate with each other to improve food safety. The spatial spillover of food safety risks relies on the networks in the food supply chain. Food supply networks can affect the temporal and spatial distribution of food safety risks by affecting the spread routes of food safety risks. Interregional collaboration based on direct supply networks complements the

asymmetry of information among interest groups and facilitates accountability. Specifically, for provinces with closer transaction relationships, local authorities tend to be more motivated to communicate and share information with one another to promote uncertainty management in the supply chain (Datta and Christopher, 2011). With closer interregional collaboration for food safety governance among relevant officials, counterparties should be more prudent in weighing the illegal benefits against the risk of penalty. When food safety problems occur, collaborative governance among local governments helps improve the accountability of violators, improve the response time for food safety risks, and avoid inefficiencies in governance caused by local government negotiations and buck-passing (Datta and Christopher, 2011; Chen et al., 2013). In this case, the opportunistic cost of food enterprises will increase accordingly, and the illegal income will be compressed. Therefore, a food supply relationship is an important element for realising effective collaborative governance of food safety.

2.1.2 Dependence on economic ties

Apart from the effects of direct economic linkages across provinces, the dependence on economic ties can also indirectly affect the efficiency of collaborative governance of food safety. On the one hand, provinces with close economic ties generally have more frequent and extensive collaborations in any field. Across these provinces, they have not only rich experiences in information sharing and cooperation, but also share relatively symmetrical bargaining power in collaborative networks. These provinces are more likely to implement cooperation since they can pursue similar goals with fewer transaction costs under the joint effort of all sides (Scharpf, 1997; Hu et al., 2019). On

the other hand, in the context of policy convergence and economic agglomeration, provinces with close economic ties tend to have similar economic attributes and consumption structures. Since the occurrence of food safety issues would trigger a deflection of food supply to third-party markets with similar development stages and dietary patterns to avoid losses (Gerber et al., 2013; Zhou et al., 2019), interregional collaboration among local officials can help avoid duplication of regulatory work and overcome the lack of investment in food safety governance under territorial governance through positive externalities of food safety governance. Therefore, the closeness of economic ties is also an important element to realise effective collaborative governance of food safety.

2.1.3 Dependence on geographical proximity

Geographical proximity can also facilitate interregional collaboration. In the research on the diffusion path of China's public policies, Wang and Lai (2013) found that the policy diffusion across governments at the same level shows significant neighbourhood effects in geographical spaces. The frequent exchange of information between neighbouring government provides favourable conditions for policy diffusion. The competition among neighbouring governments also effectively encourages policy learning and shows strong interdependent relationships. In addition, the diffusion of information across neighbourhoods is faster and more efficient than across nonadjacent areas (Wang et al., 2019). Therefore, geographical proximity is also an important element to realise effective collaborative governance of food safety.

2.2 Strategies for selecting collaborative partners

In view of the above three factors affecting the interregional collaboration for food safety governance, this paper quantifies each factor in turn, and then integrates the characteristics of the three elements to formulate a suitable zoning scheme.

2.2.1 Determining the closeness of food supply relationship across provinces

According to *Measures for the Administration of Food Safety Spot Inspections*, food safety sampling inspections in China should place emphasis on products with large consumption. This paper thus argues that the upstream and downstream transaction relationships reflected by the government's food quality and safety sampling inspection can better reflect the frequency of food transactions among regions. Since the food quality and safety situation in the upstream supply areas has a direct impact on the food quality and safety situation in the downstream purchase areas, it will be more meaningful to explore the dependence on the main supply market from the perspective of demand market. Therefore, this paper uses the names and addresses of manufacturing enterprises and sampled enterprises in the sampling information to identify the location of upstream and downstream enterprises. On this basis, it calculates the interregional transaction frequency and determines the main market of food supply in each province. The specific steps are as follows:

First, the calculation of transaction frequency. Random inspection data we used in this paper document the manufacturer and sampled firm's name and address regardless of whether it complies with legislation clauses. The information makes it possible to identify major trading partners through transaction frequency. Given this paper discusses the transaction frequency among different provinces, we eliminate transaction

data within the same province and calculate the proportion of transaction frequencies in each province against the other 30 provinces.

Second, visualization of interregional transaction frequency. Based on the transaction proportion of the main supply markets for each province, this paper applies the ForceAtlas2 layout algorithm, calculates the modularity for each force-directed method, and visualises the transaction relationships for better visual results and data compatibility. Considering that the food safety situations in upstream supply areas have a direct impact on that of the targeted province, we use the top 5 supply markets of each demand market to simplify the graphics. After filtering, a network of 31 nodes (provinces) with 155 edges is formed, as shown in Figure 1. The thickness of the edges represents the transaction intensity with other provinces.

[Figure 1 about here]

Third, identify provinces with close food transactions. Based on the interregional transaction intensity as shown in Figure 1, we preliminarily zone the provinces that are the main food supply markets for each other or have strong transaction intensity (corresponding to the thick edge in the figure). The preliminary zoning results are presented in Table 1. Within each group, nodes (provinces) with close transaction relationships are identified and clustered (Zupic and Čater, 2015). Eleven provinces;Shanxi, Inner Mongolia, Jiangxi, Shandong, Henan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang, have implicit relations with other provinces and thus are not divided into specific regions.

[Table 1 about here]

2.2.1 Calculating the closeness of economic ties and geographical proximity

Since the closeness of economic ties and the proximity across provinces are also important factors affecting the effectiveness of interregional collaboration for food safety governance, this paper further measures the degree of economic ties and geographical proximity among provinces based on Table 1.

First, it calculates the closeness of economic ties. By measuring the level of economic development and the distance across provinces, we get the index of regional economic linkage. It is believed that the higher the local GDP and population in two provinces, and the smaller the square of the distance between the two provinces, the closer the economic linkage. Therefore, this paper uses the gravity model to measure the closeness of interregional economic ties and suggests that the closer the interregional economic ties between provinces, the higher the efficiency of interregional collaborations in food safety governance. The calculation is shown in Equation (1):

$$econ_{ij} = \frac{\sqrt{gdp_i * pop_i} * \sqrt{gdp_j * pop_j}}{dist_{ij}^2} \tag{1}$$

where $econ_{ij}$ denotes the closeness of interregional economic ties, gdp_i and gdp_j are GDP in province i and j, pop_i and pop_j are the amount of population in province i and j, and $dist_{ij}$ is the particle distance between these two provinces.

Second, it identifies adjacent provinces. Generally, geographical border means proximity across regions. In this paper, geographical proximity is embodied where there is an adjacent area in geography. A geographical adjacency matrix is constructed based on the two-by-two border conditions of the administrative boundaries of each province.

Third, it identifies valid neighbouring provinces. Take province i for example, if its closeness of economic ties with province j is greater than the average, province j is regarded as a province with close economic ties to province i and both provinces have close economic ties with province i and adjacent to province i, province j is regarded as a valid neighbouring province of province i.

Finally, it integrates provinces with close transaction frequency and valid neighbouring relationships. Based on the valid neighbouring relationship identified in the previous   step and the results of Table 1, we further include the 11 provinces that failed to be partitioned into the zoning scheme. The results are shown in Table 2.

[Table 2 about here]

From the zoning results, it is not difficult to find that the zoning scheme formulated in this paper based on the three influencing collaborative governance elements is more consistent in the regions where collaborative governance of food safety has already existed; for example, the Beijing-Tianjin-Hebei integration initiative since 2016, and the Pan-Delta Economic Area Cooperation on food safety since 2019. In addition, the clustering is broadly consistent with the existing urban agglomeration. All of these confirm the reality and rationality of the zoning strategy based on social interdependence such as supply chain, economy and geography.

2.3 The evolution trend and validation of collaborative schemes

2.3.1 The calculation of coordinated regulatory performance

The level of food safety in China is the result of the coupling coordination among systems in each province and region. Although most provinces in China lack necessary,

stable, and formal collaborative alliances, some analogous effects of food safety governance may exist as a result of either interregional collaborative actions under the centralised structure of government authorities or collaborations in other fields (e.g. environmental pollution). Therefore, whether the identified collaborative schemes based on their interdependent relations work is worthy of further discussion.

Many studies have used coupling coordination degree models to express overall efficacy and coordination effect (Cheng et al., 2019; Jiang et al., 2017; Li et al., 2012b; Shi et al., 2020). To evaluate the trends of the coupling coordination degree in interregional food safety governance, the unqualified rate of products (*fr*) is used to estimate the indicator with the coupling coordination degree model in this paper.

First, since a larger *fr* indicates poorer food safety, *fr* is an indicator in the negative dimension. To avoid the error caused by different scales, the data were thus standardised by Equation (2):

$$fr'_{it} = (\max\{fr_i\} - fr_{it})/(\max\{fr\} - \min\{fr_i\}) \tag{2}$$

where *fr* represents the unqualified rate of province i in time t. fr'_{it} is the standardised value, and min $\{\cdot\}$ and max $\{\cdot\}$ are the minimum and maximum values of *fr* in certain provinces, respectively.

After this, we calculate the weight of each province according to the entropy method and variations in the provinces. Considering that there are differences in the urgency of food safety governance in different provinces, the investment and participation of local governments in the process of interregional collaboration is different, resulting in heterogeneities in the importance of food safety in various provinces. Therefore, this

paper uses entropy method to estimate the weight of each province in its specific region.

The steps are as follows:

a) The proportion of province i in time t:

$$p_{it} = fr'_{it} / \sum_{t=1}^{m} fr'_{it} \tag{3}$$

b) The entropy of province i:

$$e_i = -\frac{1}{\ln m} \sum_{t=1}^{m} p_{it} * \ln p_{it} \quad (0 \le e_i \le 1) \tag{4}$$

c) The entropy weight of province i:

$$w_{ij} = (1 - e_i) / \sum_{i=1}^{n_j} (1 - e_i) \tag{5}$$

where n_j is the number of provinces within region j and m is the number of periods.

Based on the calculation of weight for each province using the entropy method, we compute for the coupling coordination degree by equations (6)–(8) to identify the efficiency of presumptive collaborative schemes:

$$cg_j = \sqrt{C_j * T_j} \tag{6}$$

$$C_j = \left[\frac{\prod_{i=1}^{n_j} fr'_{it}}{\left(\frac{1}{n_j}\sum_{i=1}^{n_j} fr'_{it}\right)^{n_j}} \right]^{\frac{1}{n_j}} \tag{7}$$

$$T_j = \sum_{i=1}^{n_j} w_i fr'_{it} \tag{8}$$

where cg_j is the coupling coordination degree of food safety governance in region j, reflecting the extent of positive coupling and the coordination status of regulatory performance of food safety within the region, and $cg_j \in [0, 1]$. C_j represents the degree of coupling which measures the degree of correlation among provinces (Jiang et al., 2017). T_j reflects the overall level of regulatory performance of food safety.

2.3.2 The evolution trend of coordinated regulatory performance

The status of coordination under two schemes from 2015 to 2019 is displayed in Figure 2. It can be seen that six of eight regions have shown a fluctuated uptrend of coordinated regulatory performance during the sample period with a proportion of 75%, indicating that many provinces in China have a certain interregional collaboration for food safety governance.

Specifically, Group 1 in Table 2 is a collaborative area including Beijing, Tianjin and Hebei. In 2016, Beijing, Tianjin and Hebei jointly signed the Beijing-Tianjin-Hebei integration initiative to promote the interregional collaboration for food safety governance. Correspondingly, the coordinated regulatory performance of Group 1 in 2016 has shown a relatively large improvement in Figure 2. Similarly, Shanghai, Jiangsu, Zhejiang and Anhui, which participate in the Pan-Delta Economic Area Cooperation on food safety in 2019, have also shown an obvious uptrend of coordinated regulatory performance in 2019 in Group 3 accordingly. These results verify the effectiveness of the coupling coordination degree model to measure the coordinated regulatory performance of interregional collaboration for food safety.

[Figure 2 about here]

2.3.3 Validation of collaborative zoning scheme based on counterfactual analysis

While disproportionate escalating trends of coordination levels are observed under the above scenario, whether these uptrends stem from the collaboration among specific groups or the whole is still indistinct. To answer this question, we use counterfactual analysis, which measures the coordinated regulatory performance in randomly assigned collaborative schemes in the absence of the intervention of provincial interdependence,

to attribute the cause and effect between provincial interdependence and the uptrend of coordinated performance. Specifically, we randomly allocate the provinces into eight regions to calculate the coordinated regulatory performance of each region and repeat the process one thousand times to ensure the accuracy. The proportion of the uptrend of the total if counted to determine whether the improvement of the coupling coordination degree is related to regional clustering, and the proportion of larger improvement to the specific scheme if calculated to identify whether the improvement in specific grouping is efficient. By comparing the counterfactual outcomes to those calculated under the interdependence relations, we can validate the effectiveness of the presumptive collaborative scheme. The results in Table 3 indicate an improvement trend in interregional collaboration in China concerning food safety governance, but the proportion of random regions with uptrends is smaller than that of specific ones. In addition, the magnitude of coordinated improvement in regulatory performance is much smaller than that of specific grouping in both scenarios.

[Table 3 about here]

Therefore, the results show overall improvement in the coordinated regulatory performance of food safety in China, but this improvement is more efficient in regions with close interdependence rather than regions of random allocation, which indicates the rationality of our collaborative schemes. However, although China has already produced the germination of interregional governance in food safety, the coordinated evolution of interregional collaboration is still slow and volatile. To achieve more substantial and efficient progress in interregional food safety governance, relevant

influential factors affecting the coordinated regulatory performance should be further uncovered.

3 Determinants of interregional collaborative scheme

3.1 Data and modelling

3.1.1 Model specification

Based on the zoning scheme mentioned above, this paper empirically analyses the potential effects of interregional collaboration in the regulatory performance of food safety. Unlike traditional research, this paper focuses on the effects on coordinated regulatory performance rather than that of a single province. Therefore, taking the standardised unqualified rate as the dependent variable to measure the regulatory performance of food safety in province i, we first set up the traditional specification as Equation (9):

$$fr'_{it} = \alpha + \sum_k \gamma_k X_{kit} + \mu_i + \delta_t + \varepsilon_{it} \tag{9}$$

where i and t denote the province and time respectively. X_{it} represents a vector of factors that might affect the regulatory performance of food safety governance. To avoid potential omitted variables, time-fixed effects δ_t and province-fixed effects μ_i are controlled in all our specifications. ε_{it} is the error term. Based on this model, we set up Equation (10) to explore influential factors affecting the coordination degree of food safety governance:

$$cg_{jt} = \theta_0 + \sum_{m=1}^{n_j} \theta_m \frac{\sigma_{X_{jt}^m}}{X_{jt}^m} + \delta_t + \omega_j + \varepsilon_{jt} \tag{10}$$

where j denotes the groups classified above, which are composed of several provinces. cg_{jt} is the coupling coordination degree, which is estimated as the proxy of the coordinated degree in group j at time t. $\sigma_{X_{jt}^m}$ and $\overline{X_{jt}^m}$ are the standard deviation and mean of influencing factors for provinces in group j at time t, respectively. Time-fixed effects δ_t and group-fixed effects ω_j are controlled in all our specifications. ε_{jt} is the error term, and θ is the estimated parameter.

3.1.2 Variables selection

Coordinated regulatory performance of food safety. To display the coordinated regulatory performance of food safety within regions, the normalised unqualified rate fr'_{it} is used as a proxy in this paper. The data of food safety inspection records are collected from the China Food and Drug Administration (CFDA, now reconstructed into the State Administration for Market Regulation), which oversees food safety governance. Such inspection data document the product, the names and addresses of both its manufacturer and its sampled location, the results of the test, and illegal items if unqualified. A dataset with over 2.9 million records of food safety inspection for 31 provinces from 2015 to 2019 (excluding Taiwan, Hong Kong, and Macau given the lack of data) at an annual level is established in this paper. For influential factors that might affect the coordinated regulatory performance of food safety, we select variables from the perspective of governments, markets, enterprises, and consumers as follows:

Collaborative practice (ca_{ijt}). As described by Eppel et al. (2008), the collaboration efforts of governments can be viewed not only through formalised collaborative initiatives on integrated service delivery but also through informal actions or

information exchange. Though without explicit collaborative institutions or alliances to systematically cooperate on food safety governance, some collaborative practices among provinces are already in place; for example, interregional collaborations on food safety training, meetings, investigations, rules, regulations, etc. These actions help to both understand the regulatory experiences and policy views of other participants and decrease costs associated with investigating, devising, and adjusting policy solutions towards issues (Mewhirter and Berardo, 2019). Therefore, collaborative actions, even informal and single-moment events, could positively affect the coordination degree of the regulatory performance of food safety. Using text search methods, as done by Baker et al. (2016), we build a variable of *de facto* collaborative practice based on informal media coverage frequency. Specifically, we find informal media reports on the official websites of governments regarding food quality or safety. We further filter them using keywords in relation to collaborative practice, and eradicate any duplicated reports from different websites and provinces. Finally, 145 records are obtained from 2015 to 2019. The data enter the model as the number of new collaborative actions in province i with other provinces within the same group j at time t (ca_{ijt}).

Intensity of local food safety governance (Cov_*intensity*). Stricter enforcement of food safety standards can increase quality by reducing information asymmetry among governments, firms, and consumers (Leland, 1979; Zhou et al., 2021). Therefore, differences in regulatory intensity can not only reflect the gap of expenditure on market governance but also suggest room for free riders. In this paper, using relevant data from

China Statistical Yearbook and the CFDA, the intensity of local food safety governance is estimated by inspection batches per thousand people.

Market incentives (Cov_engel, Cov_pi). Provinces with similar dietary patterns are more likely to take risks together, especially during the outbreak of food safety crises (Zhou et al., 2019). For provinces that share common 'interests, concerns, or pressures', collaborations among relevant participants could effectively increase information sharing and save search costs (Mewhirter and Berardo, 2019). Considering that e-commerce might lead to a wider range of risk diffusion but reduce asymmetric information in transactions (Bakos, 2001; Kang et al., 2019), the similarity in consumption patterns might also be a potential influential factor that affects the regulatory performance and coordination degree for governments. Therefore, market incentives can not only reflect the public's demand for food safety issues but also promote attention to food safety governance. The deviation of market incentives would affect coordination as a complement to government regulation. In this paper, we estimate the consumption pattern using the proportion of per capita consumption of major food on all expenditures (*engel*). Since sufficient food supply is the basis of ensuring food safety, especially after the outbreak of food safety crises (Han et al., 2021), we introduce a supply-related factor into the model, which is the proportion of primary industry (*pi*). Relevant data are obtained from *China Statistical Yearbook*.

Safety management of local enterprises (Cov_certi). Several studies have shown that the adoption of food safety related standards and certifications can effectively improve the safety and quality of food (Chen and Li, 2017; Giacomarra et al., 2016;

Kotsanopoulos and Arvanitoyannis, 2017). The safety management of enterprises can help extend the coverage of food safety governance. The greater the difference in certification implementation, the greater the difference of the demand for government regulation, thus affecting the coordination of regional food safety governance. In this paper, we consider the deviation of the number of newly authenticated certifications (including quality standards, hazard analysis and critical control points, food safety management systems, organic certification, green certification, good agricultural practices, good manufacturing practices) within regions in the empirical analysis. The data are derived from the China National Accreditation Service for Conformity Assessment.

Consumers' attention to food safety issues (Cov_*edu*). As direct market participants, consumers' attention to food safety risks not only directly reflects the public's demand for food safety governance (Qi, 2014), but is also an effective supplementary for government regulation. Therefore, the interregional differences in consumers' attention to food safety may also affect the level of interregional collaboration for food safety governance. Since consumers with a higher education level have more access to risk information and can identify market risks more effectively (Yuan and Fan, 2021; Zhou et al., 2014), this paper also uses the average years of education to measure consumers' perception to food safety (Cov_*edu*).

[Table 4 about here]

3.2 Empirical results

Table 5 presents the estimates of some of the influential factors relating to the coordination degree of the regulatory performance of food safety. Since independent variables denote the deviation of factors, the parameters estimated in Table 5 thus can be understood as the change in coordinated regulatory performance for groups affected by a unity-sized variation in determinants.

[Table 5 about here]

The results of collaborative actions find signs and magnitudes that accord with intuition. As expected, collaborative actions within the presumptive groups can significantly improve the regulatory performance through an increased coordination degree with a magnitude of 0.004. Interregional collaborations are more targeted among participants to enhance efficiency, and the collaboration paths based on interdependence in supply chain, economy and geography are good references when enhancing the collaborative governance of food safety.

The results reported in Table 5 also show that the difference in regulatory intensity will significantly hinder the coordinated regulatory performance of food safety. Specifically, the estimated coefficients indicate 0.117 units' decline of coordinated regulatory performance following one unity-sized variation in inspection batches per thousand people. These results suggest that collaborations among participants with similar regulatory intensity in food safety can promote common development within regions.

The differences in market incentives works on different levels. Specifically, the coordination effects are significantly affected by the deviation of consumption structure

which shows a significantly negative influence on the coordination level of regulatory performance. However, the difference in primary industry proportion can effectively promote the level of collaborative performance. This might be because provinces with large proportions of agricultural production could be suppliers for those of smaller proportions. The greater the difference, the stronger the potential supply relationship among provinces.

For the safety management of local enterprises and consumers' attention to food safety issues, there are no significant effects on the coordinated regulatory performance, though the influential direction is as expected.

4. Discussions and policy implications

The cross-regional distribution of food safety risks makes interregional collaboration the prevailing trend in food safety governance. However, no substantial progress has been made in the formal interregional collaboration for food safety governance in China. The key to this is the lack of an appropriate scheme to establish collaboration. Therefore, based on collective action theory, this paper refines the three key elements of food safety collaboration from the perspective of supply chain, economy and geography to put forward a presumptive scheme for interregional collaboration. Moreover, we analyse the evolution trend and driving force of coordinated regulatory performance in each group. We conclude that China has already produced the germination of interregional governance in food safety. However, the coordinated evolution of interregional collaboration is still slow and volatile.

To explore the mechanism of promoting interregional collaboration in China, this article also explores the determinant of coordinated regulatory performance, and the results underline the importance of cooperating with provinces with similar regulatory intensity and consumption structure but marked differences in industrial structure. Collaborative actions within groups can lead to a significant and positive impact on coordinated regulatory performance as well.

The empirical results provide evidence to partner selection for interregional collaboration. Participants with close transaction networks, economic ties and geographical proximity facilitate the coordinated regulatory performance of food safety governance. Based on the collaborative clusters, the reduction of differences in regulatory intensity and consumption, and the increase of differences in production structure, can help promote coordination levels of interregional collaboration. These results generate new insights and policy implications for governments. To better promote the orderly and effective operation of interregional collaboration for food safety governance, local governments should actively promote interaction channels, especially with their trading markets or homogeneous markets. All the findings in this paper constitute the 'push' factors for the establishment of effective collaborative alliances and demonstration zones for common prosperity. Moreover, governments should attempt to add Inner Mongolia to Beijing-Tianjin-Hebei integration and add Shandong to the Pan-Delta Economic Area Cooperation to further expand the scale of interregional collaboration. Finally, governments should strengthen the performance appraisal system for their relevant officials. Specifically, local governments should

improve the evaluation and assessment system for food safety governance and regard the evaluation results of food safety as an important part of the comprehensive performance of government efforts as well as an important reference for remuneration and promotion. Since food safety governance is extensive, time-consuming, and slow work and might not be conducive to GDP growth in the short term, governments in low-income areas lack the motivation for interregional food safety governance under the GDP-based performance appraisal systems. This will further hinder the coordinated regulatory performance of food safety. Taking food safety as an important basis for performance appraisal can perhaps fundamentally motivate local governments to participate in interregional collaboration for food safety governance.

Our research is only a starting point to identify the horizontal collaborative paths for partner selection among local governments. Since the central government can also assume macro-control in establishing collaborative institutions and rules, the question of how to coordinate between central and local authorities in food safety governance at the vertical level remains unanswered.

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Tables

Table 1. Preliminary zoning scheme of interregional collaboration according to food

supply relationship

Collaborative group	Participants
1	Beijing, Tianjin, Hebei
2	Liaoning, Jilin, Heilongjiang
3	Shanghai, Jiangsu, Zhejiang, Anhui
4	Fujian, Guangdong, Guangxi, Hainan
5	Chongqing, Sichuan, Guizhou, Yunnan
6	Hubei, Hunan

Note: Restricted to data availability and consistency, Taiwan, Hong Kong, and Macau

are excluded in this paper.

Table 2. Zoning scheme of interregional collaboration according to three influential elements

Collaborative group	Participants
1	Beijing, Tianjin, Hebei, Inner Mongolia
2	Liaoning, Jilin, Heilongjiang
3	Shanghai, Jiangsu, Zhejiang, Anhui, Shandong
4	Fujian, Guangdong, Guangxi, Hainan
5	Chongqing, Sichuan, Guizhou, Yunnan
6	Jiangxi, Hubei, Hunan
7	Shanxi, Henan, Shaanxi
8	Tibet, Gansu, Qinghai, Ningxia, Xinjiang

Note: Restricted to data availability and consistency, Taiwan, Hong Kong, and Macau are excluded in this paper.

Table 3. Trend of coupling coordination degree based on counterfactual analysis

Trend of coordination degree under random grouping

	Mean differences	Linear regressive model
Probability	0.575	0.488
Finding	The coordination degree shows an overall uptrend under random grouping but with a lower probability than that under specific grouping.	

Degree of coordination improvement under random grouping

	Mean differences	Linear regressive model
Probability	0.399	0.322
Finding	The improvement of the coordination degree under random grouping is much smaller than that under both scenarios.	

Table 4. Descriptive statistics

Type	Variable	Mean	St. D.	Min	Max
Dependent variable	Coordinated regulatory performance	0.732	0.111	0.396	0.987
	Collaborative practice	48.161	27.224	10	130
	Deviation of primary industry proportion	0.487	0.279	0.030	1.014
Independent variable	Deviation of consumption structure	0.111	0.060	0.005	0.227
	Deviation of certification number	0.510	0.204	0.128	0.983
	Deviation of food safety intensity	0.533	0.249	0.126	1.264
	Deviation of consumers' attention	0.089	0.053	0.017	0.198

Table 5. Determinants of the coordination degree on regulatory performance

	cg	
ca	0.004***	(0.001)
Cov_intensity	−0.117***	(0.040)
Cov_engel	−0.701**	(0.336)
Cov_pi	1.045***	(0.206)
Cov_certi	−0.189	(0.127)
Cov_edu	−1.130	(1.213)
cons	0.387***	(0.112)
Year FE	Yes	
Group FE	Yes	
Observation	40	
Adj R-squared	0.616	

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
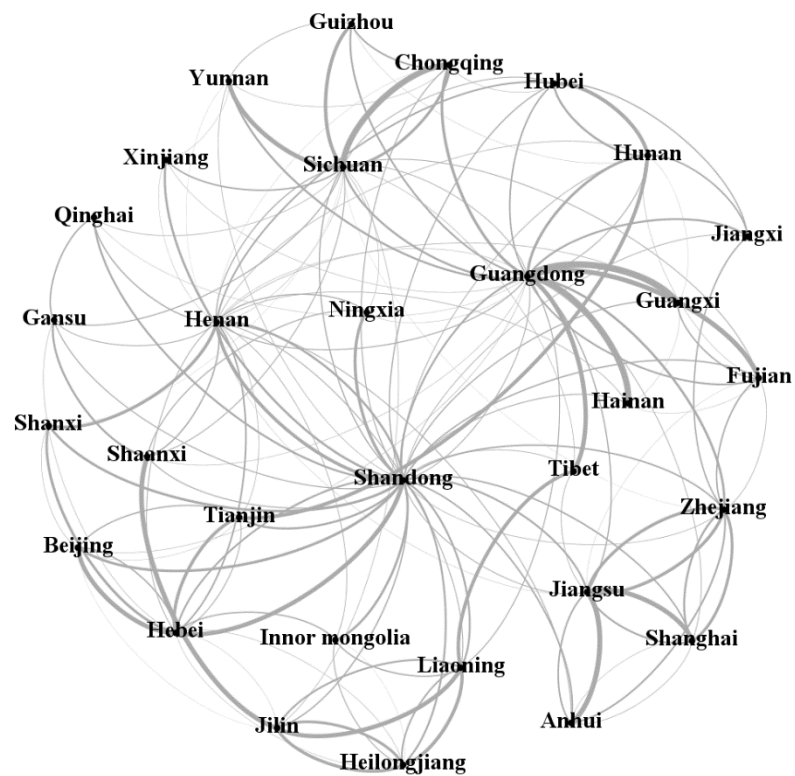
Figures

Figure 1. Social network graph based on food supply relationships.

Note: Restricted to data availability and consistency, Taiwan, Hong Kong, and Macau are excluded in this paper.
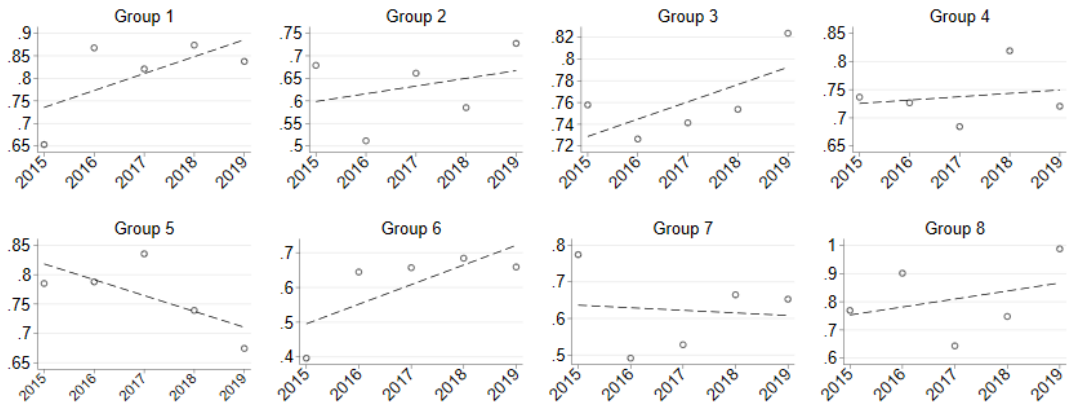
Figure 2. The trend of coupling coordination degree based on the zoning scheme.