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Basis for fulfilling responsibilities, behavior, and professionalism of government agencies and effectiveness in public–public collaboration for food safety risk management

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Food safety risk management is an important cross-boundary issue around the world from both theoretical and practical perspectives. Public–public collaboration is the most basic form of cross-boundary governance. This study investigates the main factors affecting the governance effectiveness in public–public collaboration for food safety risk management through a questionnaire survey in Jiangsu Province and Guangxi Zhuang Autonomous Region, China, using a multivariable linear regression model based on principal component analysis. The results show that although the governance effectiveness in public–public collaboration is affected by many factors, the most important of which are the behavior and capabilities of legislative, administrative regulation and enforcement, and environmental improvement government (public) agencies, professionalism of government agencies, and laws and regulations as the basis for government agencies to perform their responsibilities. This research provides a case study for the academic community to better understand the main problems facing public–public collaboration for food safety risk management in China. It also provides insights into promoting public–public collaboration in developing countries.

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Introduction

The World Health Organization (WHO) has estimated that foodborne and waterborne diseases kill 2.2 million people—mostly children—every year worldwide (WHO, 2022). In addition, there are no zero-risk circumstances in food safety. Especially since the beginning of the twenty-first century, with the wide application of new technologies, processes, and packaging materials together with the continuous development of new business forms of food consumption, food safety risks have diversified and are evolving at an accelerating pace. Although traditional chemical and biological risks still exist, many new unknown and uncertain risks have emerged (Alink et al., 2008; Newell et al., 2010; Chen et al., 2022). For example, since the global outbreak of Coronavirus disease 2019 (COVID-19), the novel coronavirus frequently detected in cold-chain food in international trade may threaten human health (Uddin et al., 2020). In this regard, Smith and McElwee (2021) stated that food safety risk management will remain a complex and long-term task in the future.

Food safety is closely related to human health, and ensuring food safety is a basic responsibility of the government. However, due to the long and complex food industry chain, multi-agency regulation is the main approach used by governments to manage food safety risks. However, due to the fragmentation, separate governance, isolation, and difficult coordination among government agencies,¹ multi-agency regulation leaves much to be desired, and there is an urgent need to apply a more scientific approach to public-public collaboration (Ceccarelli & Grando, 2020).

Numerous studies have investigated the cases and experiences of developed countries in using public-public collaboration to manage public affairs, such as infectious diseases, public health, and environmental pollution. However, few studies have systematically examined the effectiveness of public-public collaboration in food safety risk management, especially in countries in transition, including China (Hu, 2020; Hujala et al., 2022). On the basis of a literature review, this study attempts to investigate the main factors affecting public-public collaboration for food safety risk management using principal component analysis (PCA) and a multivariable linear regression model through a questionnaire survey based on the reality of multi-agency regulation of food safety in China². China was chosen as a case study because the Chinese government launched nine reforms of the food safety regulatory system from 1983 to 2023 to develop a regulatory system based on market regulation, agriculture and rural affairs, customs, and health agencies and supplemented by other participating agencies under the coordination by the Office of the Food Safety Commission of the State Council³. This gradual approach to reform has contributed to a substantial improvement in food safety in China. According to the Global Food Safety Index (GFSI) published by the Economist Intelligence Unit (EIU) in 2022, China ranked 25th in the world with a score of 74.2, an increase of 21 positions compared its rank of 46 in 2018, thereby demonstrating a great improvement in food safety (EIU, 2022). This joint regulation model involving multiple government agencies being implemented in China is also used by most countries⁴. Therefore, the successful practices and remaining challenges in China revealed in this study, as well as the reform strategy proposed, will not only provide guidance for the Chinese government to promote the reform in the future, but also provide insights for emerging countries in transition for improving their food safety risk management systems.

Public affairs and cross-boundary governance

Public governance is the most basic function of the government. However, since the 1960s, Western welfare state governments,

with the important role of “super nanny,” have generally exhibited drawbacks, such as expansion of public functions, over-staffing of operating agencies, and financial deterioration. Increasingly distinct contradictions appeared in the management of a series of major public affairs, such as public health, environmental protection, ecological diversity, social employment, market competition and monopolies, and food safety. Government was increasingly unable to manage major public affairs, which not only created a wicked problem for the government (Jean et al., 2018), but also resulted in strong public doubts about government governance capabilities (Colin, 2001). Zhang et al. (2022) argued that the source of the aforementioned contradictions is the cross-boundary characteristics of major public affairs, which cannot be solved by a single government agency. As a result, the New Public Management reform to change the mode of government management occurred, which started in the United Kingdom, then took hold in the US, subsequently extended to other Western countries, and finally spread to many countries in transition. It was a critical period for the global process of public management modernization and administrative reform, which focused on streamlining government agencies and vertically optimizing the allocation of power among government agencies (McInnes et al., 2012).

However, problems such as inequality of politics and resources, fragmentation of power, and cleavability of services became more prominent after nearly 20 years of New Public Management reform (Barnes, 2010). A typical case is the outbreak of bovine spongiform encephalopathy that originated in the United Kingdom in 1996 and caused global panic and a series of other food safety incidents, which triggered questions and reflections on the New Public Management reform (Cantley, 2004; Halkier & Holm, 2006). Hence, Western countries experienced a second reform known as the post-New Public Management in the late 1990s. The focus of reform shifted from specialization represented by vertical decentralization and institutional streamlining during the New Public Management reform to structural changes represented by cross-boundary collaboration and vertical integration, thereby allowing the transition from a single management paradigm to a rich variety of governance models (Powell et al., 2003; Christopher, 2011; Koschmann et al., 2012; Cyphers & Schultz, 2019). The aim was to alleviate the problems arising from New Public Management such as weakening of political control, cleavability of public organizational structures, and fragmentation of public services (Emerson, 2018; Cyphers & Schultz, 2019).

These two rounds of public management reforms laid an important foundation for the establishment of modern government management systems and social governance systems in Western countries (Christian et al., 2007). Since then, a variety of public governance theories, such as networked governance, multi-level governance, collaborative governance, and holistic governance, have emerged (Ansell & Gash, 2008). The common focus of these governance theories is to break through the traditional social power structure or relationship arrangement, emphasizing integration and coordination on the basis of breaking inherent barriers, such as government and social boundaries (Bovaird & Elke, 2003).

The cross-boundary governance of public affairs is a complex concept. There are different understandings of cross-boundary governance depending on the research background, perspective, and purpose. In general, previous studies have focused on three aspects of this topic. The first is the goal of cross-boundary governance. O’Leary and Bingham (2007) believed that cross-boundary governance is to facilitate multiple organizations to share information and resources across traditional boundaries, so as to make up for the lack of ability and resources faced by a

single organization in dealing with complex public issues. Lehtonen and Martinsuo (2007) regarded cross-boundary collaboration as a governance method that connects organizations with the environment and coordinates boundaries to meet public service needs. These studies emphasized that cross-boundary governance is intended to achieve a common goal.

The second aspect is the actors in cross-boundary governance. The understanding of cross-boundary governance proposed by Emerson et al. (2012) and Toppinen and Korhonen (2013) makes up for the deficiencies of O'Leary and Bingham (2007) and Lehtonen and Martinsuo (2007), arguing that cross-boundary governance is the process of policy formulation or coordinated management across the boundaries between and within the public and private sectors, non-governmental organizations, and citizens. For example, in the view of Kauffman (2015), the interstate river basin commissions in the US are a typical case of cross-boundary governance in which the federal government and state governments act as the governing bodies to coordinate policies and implement collaborative regulation in basins such as the Delaware River and the Chesapeake Bay.

The third aspect is the method of cross-boundary governance. Bryson et al. (2006) and Pardo et al. (2010) believed that cross-boundary governance is the exchange and sharing of information, resources, actions, and capabilities across the boundaries of two or more actors in order to solve problems that are difficult for a single actor to solve. Koschmann et al. (2012) also argued that cross-boundary governance is to break through the barriers of functional cleavability and institutional fragmentation in bureaucracy through diversified cooperation, such as information sharing and optimal allocation of resources, among different actors in order to solve common problems.

In line with the New Public Management reform and post-New Public Management reform in Western countries, numerous studies have been further conducted on the cross-boundary governance of public affairs. Accordingly, the concept and connotation of cross-boundary governance have also been continuously developed and enriched (Arun & Carmen, 2008). From cross-boundary governance initially established to address the drawbacks of traditional bureaucracy to the establishment of a cross-boundary governance model with the government as the core and involving other actors, such as the market and society, by overcoming the rationality of rational agents and pursuing public interests and values, a range of holistic and synergistic cross-boundary governance paradigms have been developed (Pardo et al., 2008).

There are various forms of cross-boundary governance of public affairs. Based on the actors involved, four basic types can be defined: public-public, public-private (government and private sectors, or enterprises), multi-agent (government, enterprises, and non-profit social organizations, etc.), and inter-regional (Toppinen & Korhonen, 2013; Emerson, 2018; Yu & Xiao, 2020; Kim et al., 2021; Diehlmann et al., 2021). Regardless of type, cross-boundary governance implies a process or behavior in which different actors at different levels or at the same level cooperate with each other to manage complex public affairs based on public goals by breaking through traditional organizational boundaries (Marie & Jenkins, 2001; McGuire, 2006; Lehtonen & Martinsuo, 2007; Pardo et al., 2008; Ansell & Gash, 2008; Duarte-Davidson et al., 2014; Cyphers & Schultz, 2019).

Although the cross-boundary governance of public affairs involves multiple actors and exhibits different types, the government is the most important actor. Similarly, there are many forms of public-public collaboration, but in the final analysis, there are only horizontal and vertical directions, i.e., horizontal collaboration across the boundaries of government agencies at the same level (McGuire, 2006) and vertical collaboration across

boundaries of government agencies at different levels (Cyphers & Schultz, 2019), aiming to achieve holistic governance by multiple government agencies. Holistic governance, which originated in the 1990s, is an umbrella term that aims to address the growing fragmentation of public services across government agencies (Loukis, 2008). Cohen (2006), Cyphers & Schultz (2019), and Roggero et al. (2019) pointed out that holistic governance mainly aims to solve government failures, such as power and responsibility vacancy, power and responsibility adherence, and conflicts of interest, due to excessive division of work or the ambiguity of function division, jurisdiction, and governance boundaries. Its essence is to break the shackles of traditional bureaucracy, re-integrate the overlapping or similar functions of government agencies, re-engineer the process, and form an umbrella configuration of holistic governance of public affairs for public goals by developing a sound operating mechanism (Rosemary et al., 2010; Emerson, 2018; Andrews, 2019).

Public-public collaboration for food safety risk management

Food safety risks have existed at all stages of human social development and have always been a major public issue facing all countries around the world (Krom, 2009; Nardi et al., 2020).

From agricultural production to food production, processing, storage and circulation, and consumption, the food supply chain is complex as a result of its long industrial length, low ignition point, and many contacts. To prevent food safety risks, at least 10 agencies at each level from the central to the county level of China's four-level government system undertake different regulatory functions according to their statutory duties. Many other countries also have both specific industry regulators, such as those governing the agriculture, forestry, fishery, and processing industries, and public service agencies, such as those overseeing market regulation, health, quality standards, food consumption, and imports and exports, to jointly manage food safety. The US federal government's first food safety regulator was established in 1906. To date, the US has approximately 15 agencies with different functions at the federal government level participating in food safety regulation, in addition to the more than 3000 independent regulators in states, localities, tribes, and territories working to ensure local food safety. Such decentralization can easily lead to the fragmentation of regulatory power (Yan & Jiang, 2020).

Moreover, this mode of division of powers is historically intractable. Although the first Hoover Commission proposed to reform this kind of decentralized regulation in 1949, and proposals for merging agencies have been suggested for more than half a century since then, none of them have been adopted (Vogt, 1998). Furthermore, although the collaboration among the US food safety regulators has been continuously adjusted over their long-term development, the problems of fragmentation, inconsistency, and overlap of regulation among agencies have not been well resolved (Idjagboro et al., 2020). Therefore, similar to other public governance issues, food safety risk management requires government agencies at the same level to cross boundaries to overcome fragmented governance (Fernandez et al., 2016), as well as building a clear governance authority and responsibility system across government agencies at different levels to give full play to their respective advantages, share information, effectively interact, and ultimately achieve coordinated and unified efficient governance (Rosemary et al., 2010).

Most countries where food safety is regulated by multiple government agencies have faced the challenge of how to implement public-public collaboration for food safety risk management. However, the definition of public-public collaboration is not standardized. Based on the theoretical research and political

practice around the world, the essential connotation of public–public collaboration for food safety risk management can be defined as horizontal collaboration, which crosses the boundaries of government agencies at the same level, vertical collaboration, which crosses the boundaries of government agencies at different levels, or combined horizontal and vertical cross-boundary collaboration to break through the barriers to sharing of information and resources due to boundaries and solve the problem of unclear powers and responsibilities caused by the overlapping and ambiguity of functions. This will allow actors to adapt to the characteristics of food safety risk management, such as many management links, long chain, and blurred boundaries, and solve the fragmentation, separate governance, isolation, and difficult coordination among government agencies, thereby improving the governance effectiveness in food safety risk management. This is an important contribution of this study. Moreover, this study innovatively investigates the main factors influencing public–public collaboration in the Chinese context, which provides useful guidance for other countries to implement a sound national governance mechanism for food safety regulation by multiple government agencies.

Hypotheses

Based on the results of Zhang et al. (2022) and previous studies, together with the reality of local public–public collaboration for food safety risk management in China, hypotheses concerning five dimensions are proposed in this study.

Basic characteristics of government agencies. Despite the differences among countries, a country's public agencies for social governance are in essence composed of legislative, executive, and judicial bodies at different levels (Bogdanor, 1987). Woldesenbet (2018) believed that government agencies exhibit four basic characteristic factors: legal person, hierarchy (power level), subordination, and professionalism. Legal person characteristics mean that as an organization, government agencies must have legal personality, an independent organizational system, statutory functions, and responsibilities and capabilities for public governance, which constitute the basis for public–public collaboration for food safety risk management (Ardoin et al., 2015; Mulgan, 2017). Government organizations with clear legal personality facilitate public–public collaboration.

Hierarchy characteristics refer to the administrative levels of agencies in the national governance system. Bureaucratic governments usually concentrate authority at the top of the organization. A higher position in the hierarchy corresponds to greater authority and control and a wider jurisdiction. Agencies at the highest hierarchy can lead and integrate the resources of a government system throughout the country, forming an important force with a common vision and promoting cross-boundary governance of public affairs (Sin, 2015). For example, the US Federal Food and Drug Administration (FDA) is a central authority that coordinates local governments to ensure national food safety as authorized by law (Durbin, 2004). In China, after the March 2013 reform, the Food Safety Committee of the State Council and its office performed the functions of decision-making and coordination, but not formulating regulations. According to the *Organic Law of the Central People's Government of the People's Republic of China*, the highest administrative decision-making power for food safety risk management belongs to the State Administration for Market Regulation, and local market regulators at all levels implement the regulations and administrative orders formulated by the Administration (Plangger, 2020).

Subordination in China refers to whether the superior and subordinate agencies are in a direct relationship of leading and

being led in organizational affiliation. This may be the difference between China and other countries in the management system of government agencies. In China, the State Administration for Market Regulation does not have direct leadership in terms of organizational affiliation over local market regulators at all levels. However, in the Chinese customs system, the General Administration of Customs at the central government level directly appoints the leaders of local customs at the next level and has direct leadership over these local customs. Meanwhile, the local customs and the local government are not in a relationship of leading and being led, but rather one of collaboration. The subordination characteristics of government agencies objectively affect the governance effectiveness in food safety risk management (Wu et al., 2021).

Food safety regulation has high professional requirements, which means that government agencies must have the professional competence to manage food safety risks. Government agencies with higher professional competence are more capable of managing food safety risks. Wu et al. (2019) pointed out that there are different requirements of professionalism in food safety risk management among government agencies in China. Liu (2017) compared the food safety regulation systems of 22 different countries and found that no matter what system is implemented, the establishment of regulators follows the principle of professionalism. The hypothesis that the basic characteristics of government agencies affect the governance effectiveness in public–public collaboration for food safety risk management is thus proposed. It can be subdivided into the following four hypotheses:

H1: The legal person characteristics of government agencies affect the governance effectiveness in public–public collaboration.

H2: The hierarchy characteristics of government agencies affect the governance effectiveness in public–public collaboration.

H3: The subordination characteristics of government agencies affect the governance effectiveness in public–public collaboration.

H4: The professionalism characteristics of government agencies affect the governance effectiveness in public–public collaboration.

Basis for government agencies to perform their responsibilities. There must be a basis for government agencies to carry out their responsibilities. The legal principle of responsibility emphasizes that government agencies shall manage public affairs in accordance with the law (Schwartz, 2016; Koebele, 2019). Accordingly, the laws and regulations passed by the legislature constitute the most important legal basis for government agencies. Noguera and Rodriguez (2021) compared the European Medicines Agency (EMA) and the FDA and found that despite the differences in food regulation requirements, both the EMA and FDA have a legal basis to fulfill their regulatory responsibilities. Normative documents are another basis for government agencies to fulfill their responsibilities (Apostolache and Apostolache, 2013). This is common in China. For example, the *Opinions of the Central Committee of the Communist Party of China and the State Council on Deepening Reform and Enhancing Food Safety Management* published in 2019 laid out a roadmap and timetable for food safety risk management in China. Central and local regulators usually implement normative documents with certain binding force within the scope of legal authorization to regulate important food safety matters (Zhang et al., 2022).

In Western countries, informal rules are yet another basis for promoting public–public collaboration. North (1990) subdivided institutional rules into formal, informal, and unspoken rules, positing that informal rules are unconscious rules implemented spontaneously in long-term interactions without external

authority or organizational intervention. Hume and Selbybigge (1999) and Pham and Dinh (2020) argued that informal rules, although not mandatory, are also the basis for public–public collaboration acquiesced to by government agencies due to the ambiguity of the law.

Similarly, path dependence also affects governance effectiveness in public–public collaboration. Hopf (2010) and Sedgwick and Jensen (2021) suggested that government agencies are prone to habitual behavior in a system of certain formal and informal rules. Merrill and Francer (2000) believed that path dependence exists in the US food safety regulation system, and that the division of powers among government agencies is historically intractable. In China, excessive compulsory instruments have long been implemented, whereas mixed and voluntary instruments are insufficient, which is typical of path dependence (Chen et al., 2016; Wu et al., 2022). The hypothesis that the basis for government agencies to perform their responsibilities affect the governance effectiveness in public–public collaboration for food safety risk management is thus proposed. It can be subdivided into the following four hypotheses:

H5: Laws and regulations affect the governance effectiveness in public–public collaboration.

H6: Normative documents affect the governance effectiveness in public–public collaboration.

H7: Informal rules affect the governance effectiveness in public–public collaboration.

H8: Path dependence of behavior affects the governance effectiveness in public–public collaboration.

Functions of government agencies. Yan and Jiang (2020) found that many Western countries have established multiple food safety regulators, and 18 different agencies are involved in food safety regulation at the US federal level. However, the functions, responsibilities, and powers are not the same among regulators in these countries. For example, the US Department of Agriculture (USDA) has greater authority than the FDA (Baron & Frattaroli, 2016). This is also the case in EU countries, where the European Food Safety Authority plays a leading and dominant role among multiple regulators (Mullins et al., 2022).

Powell et al. (2003) pointed out that government agencies with different functions hold and accumulate different resources; Wu et al. (2021) argued that the same is true in China. Since 1978, China has carried out nine reforms of its food safety regulation system. At present, market regulation, agriculture and rural areas, health, commerce, education, industry and informatization, and public security agencies all have some responsibility for food safety regulation. The basis for the division of regulation tasks is the different functions of the agencies.

After the reform in 2018, the positions, functions, and responsibilities of various agencies at the same level, whether the central or local level, in the system for jointly managing food safety risks no longer match. The market regulation agency has assumed the most important regulation functions and become a comprehensive dominant agency. The agriculture and rural affairs, health, and customs agencies are single-function dominant agencies responsible for regulating the production of agricultural products prior to entering the market, development (revision) of food safety standards and risk assessment, and import and export food safety regulation, respectively. Other participating agencies, such as forestry, commerce, and education agencies, are indirectly involved in governance in a particular manner and thus are all auxiliary agencies (Jen & Chen, 2017; Huang et al., 2021). The comprehensive dominant, single-function dominant, and auxiliary agencies of the Chinese government participate in governance in different manners

according to their respective functions, professions, and resources, forming a public–public collaboration system for food safety risk management with complementary functions and matching responsibilities.

It should be noted that a public agency undertakes various functions or roles in food safety management. For example, administrations for market regulation from the central to local levels not only function as legislative agencies to formulate laws and regulations, but also perform statutory administrative regulation and enforcement tasks. Therefore, what is described above is a relative classification of agencies. The governance effectiveness of an agency in public–public collaboration is inherently determined by its statutory functions and is not influenced by the classification, no matter whether it is a comprehensive dominant agency, a single-function dominant agency, or an auxiliary agency.

The hypothesis that the functions of government agencies affect the governance effectiveness in public–public collaboration for food safety risk management is thus proposed. It can be subdivided into the following three hypotheses:

H9: Comprehensive dominant agencies affect the governance effectiveness in public–public collaboration.

H10: Single-function dominant agencies affect the governance effectiveness in public–public collaboration.

H11: Auxiliary agencies affect the governance effectiveness in public–public collaboration.

Behavior and capabilities of government agencies. Lawmaking, administrative enforcement, and judicial enforcement are the main ways that different government agencies use to perform their respective functions and promote public–public collaboration for food safety risk management. Zhang et al. (2022) believed that from the perspective of public–public collaboration for food safety risk management, public agencies can be further divided into four types: legislative, administrative regulation and enforcement, judicial enforcement, and environmental improvement. Davis et al. (2021) pointed out that the behavior of public agencies participating in cross-boundary governance is determined by the authorization of laws and regulations, and their governance capabilities inherently depend on their own capabilities. The research of Bozeman (1993), Gazley (2006), Chanda et al. (2010), and Boatemaa et al. (2019) on Western countries suggested that the legislature's legislative capacity (quality) affects public–public collaboration. Lin (2018)'s study in China indicated that legislation should fully consider organically integrating the criminal justice functions of different agencies, such as criminal punishment, administrative punishment, and civil compensation functions, which helps to promote public–public collaboration. Liu and Su (2021)'s study on China revealed that the balance of interests among agencies by the legislature is conducive to improving the governance effectiveness in public–public collaboration.

The judiciary is an important part of the food safety regulation system. The collaboration among the US Department of Justice, USDA, Customs and Border Protection, and FDA has effectively combated food safety crimes (Liu et al., 2021). Similarly, the joint punishment of food safety violations and crimes by judicial and administrative agencies in China is also an important guarantee for improving the governance effectiveness in public–public collaboration (Yang, 2021). Yarkovoy (2017) and Winders (2018) argued that the capacities of administrative agencies in public–public collaboration for food safety risk management consist of decision-making, execution, and coordination, among others. Moreover, the governance effectiveness in food safety risk management also depends on the improvement of the entire

social environment (Karr et al., 2015). For example, the efforts of education, publicity, and other agencies to maintain fair market competition, protect consumer rights, publicize food safety knowledge, and actively guide public opinion are also valuable (Wertheim-Heck and Raneri, 2020; Calvo & Sclater, 2021). The hypothesis that the behavior and capabilities of government agencies affect the governance effectiveness in public–public collaboration for food safety risk management is thus proposed. It can be subdivided into the following four hypotheses:

H12: Administrative regulation and enforcement agencies affect the governance effectiveness in public–public collaboration.

H13: Judicial enforcement agencies affect the governance effectiveness in public–public collaboration.

H14: Legislative agencies affect the governance effectiveness in public–public collaboration.

H15: Environmental improvement agencies affect the governance effectiveness in public–public collaboration.

Infrastructure and culture of government agencies.

Public–public collaboration for food safety risk management is based on the information sharing and coordination of resources and capabilities among agencies, and it depends on cultural characteristics, such as organizational culture, social environment, and the application of information technology. Essentially, food safety risks are caused by information asymmetry. Effective information sharing allows integrating the chains of power, responsibility, and information across government agencies and thus further promotes public–public collaboration (Barki and Pinsonneault, 2005; Luu et al., 2018). Huang et al. (2021) also suggested that information sharing is an important factor to ensure the orderly operation of the food safety risk management system. With the rapid development of the Internet as well as science and technology, the wide application of new information technology is breaking through the barriers of information asymmetry and promoting the interconnection of information among multiple actors (Pardo et al., 2008).

Public–public collaboration is also subject to the coordination of resources and capabilities among agencies, which overcomes the lack of a single agency (Ansell & Gash, 2008). In contrast to external forces, organizational culture is the internal driving force for public–public collaboration (Zhang et al., 2012). Olson (2009) and Yesil et al. (2013) pointed out that formation of long-term mechanism of public–public collaboration depends to a large extent on whether (1) the traditional bureaucracy can be reduced, and (2) the organizational culture of innovation and collaboration can be promoted within the agencies. The greater the social concern about public affairs, the greater the need to solve such affairs, and the easier it is to generate external environmental pressure to implement public–public collaboration (Zhang & Qi, 2019). Given food safety's close relationship with human health, it is a public affair of great social concern. Tang (2011) argued that with the continuous improvement of the public's living standards and scientific literacy, high attention to food safety will continue to promote public–public collaboration. The hypothesis that the infrastructure and culture of government agencies affect the governance effectiveness in public–public collaboration for food safety risk management is thus proposed. It can be subdivided into the following five hypotheses:

H16: Information sharing among government agencies affects the governance effectiveness in public–public collaboration.

H17: The application of information technology in government agencies affects the governance effectiveness in public–public collaboration.

H18: The coordination of resources among government agencies affects the governance effectiveness in public–public collaboration.

H19: The organizational culture of government agencies affects the governance effectiveness in public–public collaboration.

H20: Social concern affects the governance effectiveness in public–public collaboration.

There is a logical relationship among the five dimensions presented in the preceding sections, which fully described the basis, infrastructure, and capabilities for a government agency to participate in cross-boundary governance of food safety. Specifically, government agencies are empowered to perform their responsibilities by the legal basis for them to participate in cross-boundary governance. The basic characteristics are the governance responsibilities they assume based on the basis for fulfilling their responsibilities. Functions reflect the differences between their roles and responsibilities in the governance system. Behavior and capabilities reflect their main mode of action and capability requirements in participating in cross-boundary governance. Infrastructure and culture reflect the social basis and cultural environment on which their participation in governance depends. Based on previous studies and the reality of China, the 20 hypothetical factors proposed in this study that may affect public–public collaboration are categorized into the five dimensions. The relationship between the five dimensions and 20 factors is depicted in Fig. 1.

Questionnaire survey and sample data

To test the hypotheses, data were collected via a survey questionnaire for analysis.

Sample source. The food safety regulator system is generally the same throughout mainland China, except in Hong Kong, Macau, and Taiwan. No matter whether considered in the vertical or horizontal direction, this system is composed of four comprehensive or single-function dominant agencies, i.e., market regulation, agriculture and rural areas, health, and customs; auxiliary agencies, such as forestry, grain, commerce, and education agencies; and legislative and judicial agencies, such as the people's congresses, public security departments, procuratorates, and courts. Considering that the focus of public–public collaboration is the relevant agencies of counties (cities, districts), townships, and subdistricts, respondents were recruited from staff of such agencies.

Questionnaire design. Based on the above hypotheses, the questionnaire included 20 measures (completely corresponding to the hypotheses) as shown in Table 1 to cover the main factors affecting the governance effectiveness in public–public collaboration. According to Shanafelt et al. (2015), Agha et al. (2016), and Jebb et al. (2021), all questionnaire items were designed using a Likert scale. To ensure the survey's validity survey, a pre-survey was conducted in Wanxiu District in Wuzhou City, Guangxi Zhuang Autonomous Region, China, before the actual survey. The data obtained from the pre-survey were tested using principal component analysis (PCA), and the questionnaire items were revised accordingly. The actual survey was only commenced after all items passed the test. In addition, technical terms in the items related to the hierarchy of government agencies and path dependence were explained in easy-to-understand language in the questionnaire.

Survey implementation. The governance capabilities in public–public collaboration in local government are closely related to local economic and social development. Jiangsu Province and Guangxi Zhuang Autonomous Region are two representative provinces with different levels of economic and social development in China. To facilitate the implementation, the survey was

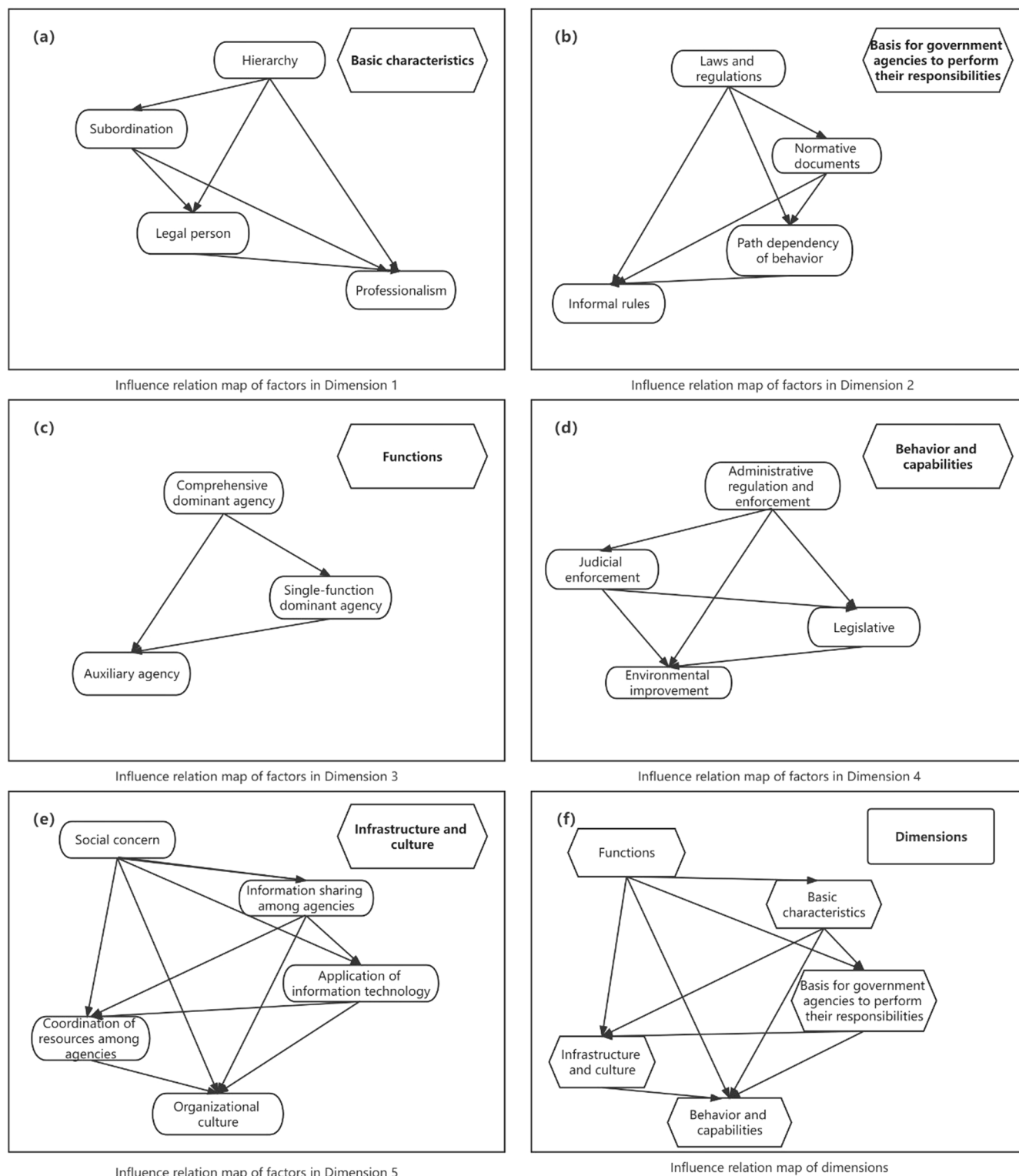


Fig. 1 Influence relation maps of factors and dimensions affecting the governance effectiveness in public-public collaboration. a–e show the influence relationship between various influencing factors within the five dimensions, while f shows the influence relationship between the five dimensions (→ indicates the direction of influence).

conducted in Jiangyin City and Runzhou District under the jurisdiction of Wuxi City and Zhenjiang City, respectively, in Jiangsu Province, and Wanxiu District and Lingchuan County under the jurisdiction of Wuzhou City and Guilin City, respectively, in Guangxi Zhuang Autonomous Region. The questionnaire was distributed to each respondent through the online working

groups of the administrations for market regulation of Jiangyin City, Runzhou District, Wanxiu District, and Lingchuan County. To ensure the quality of the survey, trained personnel were appointed to answer any questions that respondents might have. All completed questionnaires were checked to exclude those with straight-line answer patterns. Finally, 1202 valid questionnaires

Table 1 Measures of the dimensions affecting the governance effectiveness in public-public collaboration.

Dimension	Influencing factor	Measurable variable	Variable value
Governance effectiveness in public-public collaboration for food safety risk management Basic characteristics of government agencies with cross-boundary governance functions	Governance effectiveness (Y)	Governance effectiveness in public-public collaboration for food safety risk management	Very good = 1; good = 2; moderate = 3; poor = 4; very poor = 5
	Legal person (X ₁)	Ability to fulfill responsibilities, sense of responsibility, and target principles of government agencies	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Hierarchy (X ₂)	Government agencies in different hierarchies at the same level of jurisdiction have different effects on public-public collaboration	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Subordination (X ₃)	Whether the agency is directly under the central government or subordinate to the local government	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
Basis for government agencies to perform their responsibilities in cross-boundary governance	Professionalism (X ₄)	Government agencies' awareness of the importance and professionalism of public-public collaboration for food safety risk management	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Laws and regulations (X ₅)	Legal authorization and basis for public-public collaboration for food safety risk management	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Normative documents (X ₆)	Other generally binding non-legislative documents developed by competent authorities outside the scope of law	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Informal rules (X ₇)	Spontaneous initiatives between government agencies, such as cooperation agreements	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
Functions of government agencies in cross-boundary governance	Path dependency of behavior (X ₈)	Government agencies are subject to the inertia of historical and traditional institutions	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Comprehensive dominant agency (X ₉)	Comprehensive dominant agencies have comprehensive functions; for example, the State Administration for Market Regulation has an integrated function of regulating food safety	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Single-function dominant agency (X ₁₀)	Single-function dominant agencies have single functions; for example, the Ministry of Agriculture and Rural Affairs is responsible for regulating the quality and safety of edible agricultural products	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Auxiliary agency (X ₁₁)	Auxiliary agencies are not directly engaged in food safety risk management; for example, the Ministry of Education is responsible for enhancing public awareness and education on food safety risks	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
Behavior and capabilities of government agencies in cross-boundary governance	Administrative regulation and enforcement (X ₁₂)	Administrative regulation and enforcement agencies are administrative agencies, such as market regulation, agriculture and rural affairs, commerce, and customs agencies, that are authorized to enforce the law, generally by administrative laws and occasionally by the State Council	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Judicial enforcement (X ₁₃)	Judicial enforcement agencies are national judicial authorities, such as public security, procuratorates, courts, and judicial bureaus, that handle criminal cases and impose penalties in accordance with legal procedures	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Legislative (X ₁₄)	Legislative agencies are agencies that emphasize governance by good laws through legal guarantees, such as the legislative affairs offices of the people's congresses and the legal affairs bureaus of the governments	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Environmental improvement (X ₁₅)	For example, the cyber administrations guide appropriate and legal online dissemination of information; and the publicity departments properly guide public opinion, publicize food safety knowledge, and create a favorable public opinion environment for food safety management	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5

Table 1 (continued)

Dimension	Influencing factor	Measurable variable	Variable value
Infrastructure and culture of government agencies in cross-boundary governance	Information sharing among agencies (X_{16})	Extensive information exchange between agencies helps clarifying each other's role, promote tacit coordination and cooperation, and enhance the ability to manage public affairs	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Application of information technology (X_{17})	Inter-agency information sharing to connect different information systems so that data can be shared within the government using a common conceptual model	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Coordination of resources among agencies (X_{18})	Information sharing, resource interdependence, and mutual technical assistance among government agencies	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Organizational culture (X_{19})	Organizational culture belongs to "soft institutions" together with customs and morals. The cultural elements required for public-public collaboration include the willingness to actively cooperate, the pursuit of common goals, and the cultivation of cooperative trust, etc.	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5
	Social concern (X_{20})	Level of public concern and debate about public-public collaboration	Very important = 1; important = 2; moderately important = 3; less important = 4; not important = 5

Table 2 Basic demographics of respondents.

Item	Description	Frequency	Proportion (%)
Gender	Male	551	45.84
	Female	651	54.16
Job title	Staff member	885	73.63
	Section chief	302	25.12
	Division chief	15	1.25
Education	High school (including vocational high school) or lower	100	8.32
	Junior college	246	20.47
	Bachelor's degree	781	64.97
	Master's degree or higher	75	6.24
Age	18–30 years	257	21.38
	31–39 years	429	35.69
	40–49 years	325	27.04
	50–54 years	121	10.07
	55–60 years	70	5.82
Years of working experience	5 years or less	251	20.88
	6–10 years	264	21.96
	11–19 years	268	22.30
	20–29 years	264	21.96
	30 years or more	155	12.90
Agency type	Market regulation	502	41.76
	Agriculture and rural affairs (including forestry and grassland)	44	3.66
	Health	73	6.07
	Customs	19	1.58
	Public security	33	2.75
	Procuratorate	21	1.75
	Court	22	1.83
	Education, science and technology, and industry and information technology	209	17.39
	Food and strategic reserves	29	2.41
	Civil affairs	31	2.58
	Judiciary	28	2.33
	People's congress	24	2.00
	Others	167	13.89

were obtained. Due to the effective organization, the survey covered 82.18% of the eligible staff in Jiangyin City, Runzhou District, Wanxiu District, and Lingchuan County. The demographics of respondents, including agency types, are shown in Table 2. Because the grassroots staff in food safety regulation in China are concentrated in the market regulation, agriculture and rural affairs, and health agencies, the proportion of respondents in different government agencies shown in Table 2 conforms to reality⁵.

Research methods, data testing, and PCA

Research methods. Governance effectiveness in public–public collaboration for food safety risk management is affected by many dimensions. Moreover, each dimension includes several factors. Such dimension and factors are not independent of each other. A simple and effective method is to further identify the most important factors affecting the governance effectiveness in public–public collaboration for food safety risk management by analyzing the relationships among all influencing factors (Wang, 2008; Zhou et al., 2011). Massy (1965), Liu et al. (2003), Mei et al. (2010), Watanabe et al. (2012) and Roberts and Whited (2013) examined PCA from the perspective of statistical theory, and demonstrated it to be an effective method for analyzing complex relationships among multiple variables. They also found that it usually does not require robustness checks⁶ because it overcomes the effects of collinearity and avoids the endogeneity among variables. Therefore, this study uses PCA to integrate all factors influencing the governance effectiveness in public–public collaboration for food safety risk management into several uncorrelated comprehensive index variables to reduce the dimensionality of the data set (Jolliffe, 2002; Merlino et al., 2022), and establish a multivariable linear regression model to identify the key factors affecting public–public collaboration.

Data testing. Data collected from the survey were evaluated by the Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity using SPSS software. The results are given in Table 3. Based on Kaiser and Rice (1974), the correlation coefficients between variables can be determined by the KMO sampling adequacy test. A KMO value of greater than 0.9 indicates that the variables have many common factors, and it is thus appropriate to use PCA. The Bartlett's test of sphericity is used to determine

Table 3 KMO and Bartlett tests for sample data.

KMO measure of sampling adequacy	0.932
Bartlett's test of sphericity	Approx. chi-square 12,727.812
	Degree of freedom 190
	Significance (p) 0.000

whether the correlation matrix of the variables is an identity matrix. As shown in Table 3, the KMO value is 0.932, indicating that the correlation between variables is strong.

Table 3 also indicates that the approximate chi-square for Bartlett's test of sphericity is 12,727.812, and the significance level (p) is 0.000, which is <0.05 , indicating that there is a significant difference between the correlation coefficient matrix and the identity matrix. This demonstrates that the variables have common factors, and it is appropriate to use PCA (Zhang & Fang, 1982; Hardle, 2019).

PCA. The initial factor loading matrix of the principal components $F_1, F_2, \dots, F_p$ was calculated using SPSS (Izenman, 2008). Using the data in the initial component loading matrix and the eigenvalues of the principal components, the coefficients corresponding to factors in pp principal components can be calculated. The relationship between the pp principal components and the 20 factors affecting public-public collaboration for food safety risk management is thus obtained:

$$F_i = a_1X_1 + a_2X_2 + \dots + a_{20}X_{20} \quad (1)$$

where F_i is the i -th principal component, and a_i is the principal component factor score coefficient of X_i .

The 20 independent variables are integrated into uncorrelated comprehensive index variables to reduce data dimensionality using PCA. A total of nine principal component factors $F_1, F_2, \dots, F_9$ are obtained based on the criterion that the cumulative variance contribution rate is greater than 80% (Jolliffe, 2002; Fu, 2007). Moreover, the eigenvalue of the first principal component F_1 is 8.526, which explains 42.630% of the total variance of the 20 variables. Similarly, the eigenvalues of principal components F_2 and F_3 are 1.776 and 1.537, respectively, which explain 8.882% and 7.684% of the total variance of the 20 variables, respectively. Finally, the nine principal component factors extracted by PCA had a cumulative variance contribution rate of 80.258%, thereby fully summarizing the information of 20 independent variables while minimizing data loss (Jolliffe, 2002; Hardle, 2019). Table 4 presents the initial factor loading matrix of the nine principal components $F_1, F_2, \dots, F_9$.

Because PCA is a special case of factor analysis (Juneja, 2012), which has great advantages in the interpretation and classification of multivariate common factors (Ferrara et al., 2019), the principal component factors are classified and named by factor analysis. As shown in Table 5, the rotated factor loading matrix is obtained by Varimax rotation in factor analysis. The nine principal component factors are then classified and named based on Table 1. F_1 is named as the factor of "behavior and capabilities", which includes administrative regulation and enforcement agencies (X_{12}), judicial enforcement agencies (X_{13}), legislative agencies (X_{14}). F_2 and F_6 are classified as the factor of "basis for fulfilling responsibilities". F_2 includes informal rules (X_7) and path dependence of behavior (X_8). F_6 includes laws and regulations (X_5) and normative documents (X_6). F_3 and F_8 are classified as the factor of "functions". F_3 includes single-function dominant agencies (X_{10}) and auxiliary agencies (X_{11}). F_8 includes comprehensive dominant agencies (X_9). F_4 and F_7 are classified as the factor of "infrastructure and culture". F_4 includes information sharing

among agencies (X_{16}), application of information technology (X_{17}). F_7 includes social concern (X_{20}). F_5 and F_9 are classified as the factor of "basic characteristics". F_5 includes legal person (X_1) and hierarchy (X_2) and F_9 includes professionalism (X_4).

The score coefficients of the nine principal components factors were determined by regression estimation in SPSS as shown in Table 6. The relationship between the nine principal components and the influencing factors was thus obtained (Hardle, 2019).

The functional relationship between the first principal component F_1 and the 20 influencing factors is shown in Eq. (2):

$$\begin{aligned} F_1 = & -0.013X_1 - 0.071X_2 - 0.009X_3 - 0.023X_4 + 0.601X_5 \\ & + 0.156X_6 - 0.050X_7 + 0.018X_8 - 0.082X_9 - 0.190X_{10} \\ & - 0.108X_{11} + 0.434X_{12} - 0.105X_{13} + 0.546X_{14} + 0.012X_{15} \\ & - 0.033X_{16} - 0.117X_{17} - 0.062X_{18} - 0.102X_{19} - 0.084X_{20} \end{aligned} \quad (2)$$

The functional relationships for the other principal components $F_2, F_3, \dots, F_9$ can be obtained in the same manner, which are not listed here due to space limitations.

PCA-based multivariable linear regression model specification and results. To better reflect the influence of 20 factors on governance effectiveness in public-public collaboration for food safety risk management, a multivariable linear regression model is formulated as follows based on the above PCA results:

$$Y = b_0 + b_1F_1 + b_2F_2 + \dots + b_pF_p + e \quad (3)$$

where Y is the governance effectiveness in public-public collaboration for food safety risk management; $F_1, F_2, \dots, F_9$ are the principal components affecting Y ; b_i is the regression coefficient; b_0 is the regression constant; and e is the fitting error. A regression analysis of Eq. (3) was performed using SPSS. The results are shown in Table 7.

As shown in Table 7, the adjusted R^2 is 0.748, indicating that the nine extracted principal component factors, $F_1, F_2, \dots, F_9$ explain 74.8% of the variation in the governance effectiveness in public-public collaboration for food safety risk management, which is higher than the 70% goodness of fit (Sun, 2013; Robert, 2020). This suggests that the equation between the independent and dependent variables is reasonable. Moreover, the adjusted R^2 offsets the effect of sample size on R^2 (Johnson & Wichern, 1992), indicating that model (3) fits the data better. The F -statistic is 397.375, and the significance level (p) is 0.000, which is <0.05 . The null hypothesis that the regression coefficients are all zero is thus rejected, indicating that the regression equation developed is valid (Chalmer, 2020).

Furthermore, the regression coefficients and collinearity statistics are obtained as shown in Table 8 by estimating the regression coefficients of Eq. (3).

As shown in Table 8, the variance inflation factors (VIF) of the principal components $F_1, F_2, \dots, F_9$ are all approximately 1. It indicates that the principal components are orthogonal to each other, eliminating multicollinearity among the influencing factors (Wang, 2017). Moreover, the significance levels (p) of the regression coefficients of $F_1, F_2, \dots, F_9$ are all 0.000, which is <0.05 , indicating that all principal components have a significant effect on Y (Chalmer, 2020). Thus, the regression equation of Y on the principal component indices $F_1, F_2, \dots, F_9$ is obtained as follows:

$$\begin{aligned} Y = & -0.079 + 0.531F_1 + 0.104F_2 + 0.211F_3 + 0.249F_4 \\ & + 0.152F_5 + 0.298F_6 + 0.150F_7 + 0.106F_8 + 0.254F_9 \end{aligned} \quad (4)$$

Table 4 Initial factor loading matrix.

Variable	1	2	3	4	5	6	7	8	9
X ₁	0.479	-0.162	0.617	0.359	0.040	0.148	-0.030	-0.187	0.085
X ₂	0.522	-0.043	0.597	0.317	-0.068	0.176	-0.181	-0.109	0.015
X ₃	0.380	0.709	0.094	0.082	-0.037	0.126	0.164	0.179	-0.064
X ₄	0.561	-0.036	0.434	-0.001	-0.228	-0.129	0.242	0.521	0.029
X ₅	0.727	-0.165	-0.260	0.295	0.273	-0.031	-0.013	0.083	-0.029
X ₆	0.768	-0.069	-0.273	0.164	-0.085	0.008	-0.056	0.051	-0.018
X ₇	0.435	0.782	0.008	0.040	0.062	-0.022	-0.025	-0.090	0.028
X ₈	0.515	0.686	-0.008	-0.104	0.203	0.006	-0.075	-0.068	0.067
X ₉	0.624	-0.115	0.099	-0.032	0.093	-0.252	0.611	-0.315	0.070
X ₁₀	0.706	0.014	-0.203	0.135	-0.422	-0.234	-0.102	-0.065	0.094
X ₁₁	0.696	0.066	-0.346	0.199	-0.360	-0.158	-0.075	-0.117	0.047
X ₁₂	0.714	-0.156	-0.243	0.219	0.281	-0.041	0.060	0.020	0.002
X ₁₃	0.660	-0.076	0.317	-0.322	0.069	-0.292	-0.196	-0.056	-0.162
X ₁₄	0.713	-0.138	-0.196	0.191	0.308	-0.015	-0.063	0.269	-0.037
X ₁₅	0.691	-0.036	0.228	-0.241	0.110	-0.364	-0.184	-0.003	-0.219
X ₁₆	0.753	-0.170	0.056	-0.244	0.018	0.177	-0.080	0.080	0.194
X ₁₇	0.713	-0.102	-0.049	-0.367	-0.006	0.137	-0.010	0.086	0.428
X ₁₈	0.737	-0.100	-0.081	-0.212	0.071	0.207	-0.039	-0.187	0.076
X ₁₉	0.781	-0.028	-0.143	-0.099	-0.171	0.196	-0.008	-0.070	-0.188
X ₂₀	0.678	-0.110	-0.080	-0.177	-0.126	0.388	0.174	-0.018	-0.402

Table 5 Rotated factor loading matrix.

Variable	1	2	3	4	5	6	7	8	9
X ₁	0.152	0.026	0.032	0.100	0.862	0.118	0.050	0.166	0.098
X ₂	0.107	0.130	0.119	0.099	0.835	0.179	0.112	-0.020	0.131
X ₃	0.054	0.790	0.068	-0.017	0.078	-0.052	0.164	0.016	0.272
X ₄	0.132	0.111	0.129	0.174	0.271	0.231	0.100	0.119	0.822
X ₅	0.139	0.105	0.130	0.250	0.218	0.774	0.144	0.117	0.116
X ₆	0.256	0.150	0.169	0.157	0.156	0.776	0.126	0.115	0.134
X ₇	0.069	0.872	0.179	0.043	0.069	0.102	0.013	0.052	-0.036
X ₈	0.157	0.821	0.081	0.211	0.032	0.205	0.031	0.044	-0.074
X ₉	0.237	0.093	0.168	0.173	0.154	0.197	0.145	0.862	0.117
X ₁₀	0.236	0.136	0.790	0.189	0.107	0.187	0.101	0.095	0.126
X ₁₁	0.321	0.192	0.786	0.139	0.047	0.085	0.162	0.100	0.015
X ₁₂	0.735	0.092	0.220	0.187	0.113	0.124	0.143	0.214	-0.001
X ₁₃	0.797	0.083	0.250	0.145	0.139	0.117	0.141	0.119	0.020
X ₁₄	0.789	0.110	0.141	0.201	0.092	0.181	0.132	-0.002	0.153
X ₁₅	0.540	0.135	0.495	0.227	0.104	0.114	0.263	0.050	0.084
X ₁₆	0.307	0.072	0.170	0.641	0.211	0.255	0.256	0.049	0.151
X ₁₇	0.234	0.121	0.205	0.818	0.055	0.170	0.124	0.121	0.155
X ₁₈	0.312	0.137	0.205	0.534	0.171	0.224	0.363	0.164	-0.116
X ₁₉	0.302	0.180	0.388	0.299	0.130	0.209	0.563	0.075	0.044
X ₂₀	0.253	0.095	0.150	0.219	0.105	0.144	0.817	0.116	0.111

Based on Eq. (2) and the principal component factor score coefficients from PCA, the regression equation of Y on the 20 influencing factors $X_1, X_2, \dots, X_{20}$ is obtained as follows:

$$\begin{aligned}
 Y = & -0.079 - 0.010X_1 - 0.009X_2 + 0.023X_3 + 0.195X_4 \\
 & + 0.161X_5 + 0.082X_6 - 0.032X_7 - 0.002X_8 + 0.006X_9 \\
 & + 0.011X_{10} - 0.005X_{11} + 0.137X_{12} + 0.081X_{13} + 0.215X_{14} \\
 & + 0.119X_{15} + 0.063X_{16} + 0.047X_{17} - 0.018X_{18} \\
 & - 0.003X_{19} - 0.006X_{20}
 \end{aligned}
 \quad (5)$$

It can be seen from Eq. (5) that the regression coefficients of legislative agencies (X_{14}) and professionalism (X_4) rank first and second among all 20 influencing factors, being 0.215 and 0.195, respectively. This finding suggests that these two factors have the strongest positive correlation with Y , which supports H14 and H4. Thus, it can be judged that they are the two key factors affecting Y .

This is highly consistent with the findings of Gazley (2006), Woldeesenbet (2018), and Zhang et al. (2022). The regression coefficients of laws and regulations (X_5), administrative regulation and enforcement agencies (X_{12}), and environmental improvement agencies (X_{15}) are 0.161, 0.137, and 0.119, respectively. These values suggest that these three factors have a positive correlation of varying strength with Y , which supports H5, H12, and H15. Thus, they are also key factors affecting Y . This is highly consistent with the findings of Karr et al. (2015), Yarkovoy (2017), Boatemaa et al. (2019), and Koebele (2019). The absolute values of the remaining factors' regression coefficients are all small and quite different from those of the aforementioned five factors. Such a finding indicates that the remaining factors have very limited influence on Y and thus cannot be considered as key factors.

Robustness check. To verify the robustness of the above conclusions, control variables are used to eliminate five independent

Table 6 Score coefficients of principal components factors.									
Variable	1	2	3	4	5	6	7	8	9
X ₁	−0.013	−0.029	−0.044	−0.015	0.645	−0.146	−0.086	0.093	−0.151
X ₂	−0.071	0.006	0.046	−0.050	0.618	−0.053	0.000	−0.200	−0.105
X ₃	−0.009	0.403	−0.104	−0.130	−0.033	−0.204	0.164	−0.020	0.329
X ₄	−0.023	−0.032	−0.023	−0.020	−0.087	−0.050	−0.067	−0.015	1.023
X ₅	0.501	−0.019	−0.104	−0.143	0.005	−0.057	−0.101	−0.025	−0.047
X ₆	0.156	−0.034	0.214	−0.056	−0.017	−0.085	0.041	−0.125	0.025
X ₇	−0.050	0.440	0.026	−0.042	0.021	0.002	−0.101	0.028	−0.147
X ₈	0.018	0.417	−0.134	0.125	−0.035	0.082	−0.141	−0.019	−0.211
X ₉	−0.082	−0.008	−0.050	−0.076	−0.061	−0.081	−0.045	1.148	−0.008
X ₁₀	−0.190	−0.074	0.675	−0.035	−0.002	0.012	−0.185	−0.034	0.053
X ₁₁	−0.108	−0.030	0.633	−0.100	−0.010	−0.072	−0.082	−0.005	−0.070
X ₁₂	0.434	−0.010	−0.126	−0.082	−0.019	−0.065	−0.102	0.127	−0.083
X ₁₃	−0.105	−0.046	−0.039	−0.086	−0.049	0.702	−0.024	−0.063	−0.079
X ₁₄	0.546	0.001	−0.229	−0.073	−0.079	0.012	−0.111	−0.219	0.156
X ₁₅	0.012	−0.025	−0.036	−0.230	−0.114	0.735	−0.042	−0.072	−0.029
X ₁₆	−0.033	−0.044	−0.092	0.517	0.025	−0.059	−0.043	−0.147	0.048
X ₁₇	−0.117	−0.008	−0.032	0.838	−0.087	−0.196	−0.295	−0.005	0.096
X ₁₈	−0.062	0.001	−0.070	0.346	0.059	−0.033	0.151	0.056	−0.330
X ₁₉	−0.102	−0.013	0.108	−0.058	−0.012	0.006	0.499	−0.090	−0.084
X ₂₀	−0.084	−0.031	−0.164	−0.214	−0.059	−0.044	0.956	−0.007	0.034

Table 7 Model overview.					
Model	R	R ²	Adjusted R ²	F	Significance (p)
1	0.866	0.750	0.748	397.375	0.000

variables: normative documents (X₆), auxiliary agencies (X₁₁), judicial enforcement agencies (X₁₃), organizational culture (X₁₉), and social concern (X₁₉). Linear regression based on principal component analysis was performed on the remaining 15 independent variables and the dependent variable to obtain the regression Eq. (6) between the 15 influencing factors and Y:

$$Y = -0.095 - 0.001X_1 + 0.001X_2 - 0.015X_3 + 0.215X_4 + 0.111X_5 - 0.014X_7 + 0.023X_8 + 0.025X_9 + 0.033X_{10} + 0.182X_{12} + 0.293X_{14} + 0.152X_{15} + 0.077X_{16} + 0.020X_{17} - 0.042X_{18}$$

(6)

The five largest coefficients were for professionalism (X₄), laws and regulations (X₅), administrative regulation and enforcement (X₁₂), legislative (X₁₄), and environmental improvement (X₁₅), which is consistent with the above conclusions.

Conclusions and discussion

Compared with the ordinary multivariable linear regression model, the multivariable linear regression model based on PCA eliminates multicollinearity among multiple influencing factors as independent variables, thus allowing the model to more objectively reflect the influence of different factors on the governance effectiveness in public–public collaboration for food safety risk managements. This study reveals that the behavior and capabilities of legislative (X₁₄), administrative regulation and enforcement (X₁₂), and environmental improvement (X₁₅) government (public) agencies, professionalism (X₄), and laws and regulations (X₅) are the most important factors affecting the governance effectiveness in public–public collaboration.

It has been mentioned previously that the above conclusions are supported by previous studies. However, the other 15 factors assumed in this study are not the key factors affecting the governance effectiveness in public–public collaboration in China.

Although this finding is more or less inconsistent with previous studies, it is not difficult to understand. Here, informal rules (X₇) and organizational culture (X₁₉) are used as examples to illustrate this. It has been mentioned in the hypotheses that informal rules, although not mandatory, have become the basis for public–public collaboration acquiesced by government agencies in Western countries due to the ambiguity of the law (Hume and Selbybigge, 1999; Robinson, 2005). However, public–public collaboration in China has been shown to be based on legal formal rules, and informal rules are basically ineffective (Zhang et al., 2022). The possible reason is that, unlike Western countries, government agencies in China have long lacked strong external regulatory constraints and sufficient legal supervision. In this case, government agencies have discretion in major matters. Once policy makers use informal rules that go beyond laws and regulations for rent seeking, it will cause immeasurable harm. Therefore, it is necessary to promote public–public collaboration based on laws and regulations in China at this stage.

As another example, in Western countries, the culture of trust among government agencies is considered a resource to reduce the opportunistic behavior caused by resource exchange uncertainty and information asymmetry during public–public collaboration (Waardenburg et al., 2019; Scott and Boyd, 2020). However, farming culture has long been dominant in China, which has resulted in the deeply rooted smallholder ideology and traditional culture of “hoeing one’s own potatoes”. This naturally also affects government agencies and cross-boundary governance among them. It should also be noted that the other 15 factors not identified as key factors are not useless. These secondary factors may become key factors in the future as the food safety risk management system continuously improves.

This study investigates the case of public–public collaboration in China based on international experience. Moreover, joint regulation by multiple government agencies is used by most countries. Therefore, the conclusions and policy recommendations of this study not only provide insights for the Chinese government, especially local governments, but also provide guidance for other developing countries seeking to improve food safety risk management systems. The results of this study make positive contributions in this context. The main innovative conclusions are as follows:

Table 8 Regression coefficients of principal component factors and collinearity statistics.

Model	Unstandardized coefficient		Standardized coefficient	t	Significance (p)	Collinearity statistics	
	B	Standard deviation	Beta			Tolerance	VIF
(Constant)	−0.079	0.028		−2.878	0.004		
F ₁	0.531	0.013	0.599	41.191	0.000	0.992	1.008
F ₂	0.104	0.008	0.204	13.810	0.000	0.962	1.039
F ₃	0.211	0.010	0.312	21.531	0.000	0.997	1.003
F ₄	0.249	0.012	0.296	20.328	0.000	0.987	1.014
F ₅	0.152	0.019	0.116	7.961	0.000	0.985	1.015
F ₆	0.298	0.014	0.310	20.856	0.000	0.951	1.051
F ₇	0.150	0.012	0.178	12.116	0.000	0.977	1.024
F ₈	0.106	0.013	0.116	7.996	0.000	0.996	1.004
F ₉	0.254	0.012	0.304	20.428	0.000	0.950	1.053

First, the governance effectiveness in public–public collaboration is affected by many factors. Among them, the most critical factor is the behavior and capabilities of legislative agencies. In general, legislative agencies are not directly involved in food safety risk management. Nevertheless, a mature, effective, and complete legal system has a profound impact on the behavior of government agencies in public–public collaboration. Therefore, for developing countries that adopt joint regulation by multiple government agencies, it is necessary to strengthen the construction of legislative bodies, thereby improving the legal system, solving the problem of legislative fragmentation, and eliminating the gaps, overlapping, or ambiguities in food safety laws. In particular, it is necessary to enhance the use of normative documents in China due to its unique system. For example, the *Opinions of the Central Committee of the Communist Party of China and the State Council on Deepening Reform and Enhancing Food Safety Management* is a long-term normative document that should be fully implemented. Moreover, because legislation is a process that takes a long time, making use of normative documents can temporarily compensate for the gaps and ambiguities in the legal system.

Second, the behavior and capabilities of administrative regulation and enforcement agencies and environmental improvement agencies significantly affect the governance effectiveness in public–public collaboration. Therefore, for developing countries that adopt joint regulation by multiple government agencies, public–public collaboration should focus on building administrative regulation and enforcement agencies and developing a governance system for food safety management composed of government agencies with clear powers and responsibilities and complementary functions from the central government to the local government in order to solve the persistent problem of fragmentation and buck-passing among agencies. Moreover, the role of education, publicity, and other environmental improvement agencies should be brought into full play so that multiple government agencies work together to manage food safety risks.

Third, the laws and regulations as the basis for government agencies to perform their responsibilities are also a key factor. In fact, the laws and regulations as the basis for government agencies to perform their responsibilities and the legislative government (public) agencies match, reflecting the inherent requirement of a modern law-based society that “governments must perform all statutory duties and may not do anything not authorized by law.” Therefore, efforts must be made to form a complete and interconnected system of laws and regulations to provide a fundamental basis for managing food safety risks, as well as to improve the law enforcement environment and overcome local protectionism. Maintaining the stability of laws and regulations is as important as advancing reforms in a gradual manner in

developing countries that adopt joint regulation by multiple government agencies.

Fourth and lastly, the professionalism of government agencies is another key factor affecting governance effectiveness. This is not difficult to understand and reflects the fact that food safety risk management is very professional. Government agencies should be equipped with technical capabilities according to their functions and achieve cross-boundary governance through professional experimental facilities, equipment, technical tools, and specialized talents. Therefore, it is necessary to strengthen the professional development of government agencies to build a professional talent team and ensure adequate technical facilities. Such steps would help ensure that government agencies have the professional competence to fulfill their responsibilities, thereby enhancing their cross-boundary governance capacities.

Moreover, it should be pointed out that the other 15 factors assumed in this study, although not critical, deserve considerable attention from developing countries that adopt joint regulation by multiple government agencies, including China, in the process of cross-boundary governance. For example, informal rules are also the basis for promoting cross-boundary governance among government agencies in Western countries. However, the implementation of informal rules in food safety risk management by local governments in China has just begun. Therefore, it is difficult to reflect the importance of informal rules through empirical research, at least at present. However, this does not negate the role of informal rules in governance.

Finally, there are limitations in this study that must be pointed out. The data used in the PCA-based multivariable linear regression model were collected from the staff of agencies involved in food safety regulation in four counties (cities, districts) and their townships and subdistricts in Jiangsu Province and Guangxi Zhuang Autonomous Region, China. However, there are 2844 counties (cities, districts) in 31 provinces, autonomous regions, and municipalities directly under the Central Government in mainland China. Therefore, the data obtained from the survey cannot represent the whole of China. The generality of the conclusions therefore needs further research.

In addition, there may be overlaps among the 20 hypotheses (influencing factors) proposed in this study. Efforts are needed to address this problem in future research. Readers should pay attention to the limitations of the conclusions due to these possible overlaps. Moreover, the mechanisms by which these factors affect governance effectiveness have not been examined.

Furthermore, the conclusions of this study are based on a questionnaire survey among respondents. The respondents' responses to the questionnaire were affected by their knowledge in management or economics. Besides, five response options were designed for each item based on a Likert scale, which limited the

choices for respondents. For example, there might be a small number of respondents who did not have a clear understanding of governance effectiveness, so they could not make the truest choice from the five established options. Moreover, using only one question about attitude as a proxy variable may not be sufficient to elicit the respondents' truest evaluation.

Respondents might also overestimate the importance of their government agencies. This study focuses on the correlation of the 20 hypothetical factors (X) with governance effectiveness in public-public collaboration (Y). However, it does not delve into whether there is a clear causal relationship between X and Y . All these problems need to be addressed in future research. Nevertheless, this research provides a case study for the academic community to better understand the main problems facing public-public collaboration for food safety risk management, and it provides policy decision-making support for promoting public-public collaboration.

Data availability

Datasets are available from authors upon reasonable request. The datasets are also available from the Supplementary Information in this paper.

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Notes

- 1 A country's public agencies for social governance are composed of legislative, executive, and judicial bodies at different levels, and significant differences exist in the public agency system among countries around the world. For example, the state agencies (public agencies) in the US are composed of legislative, executive, and judicial bodies that are independent of each other and perform their duties independently. Although China has also established legislative, executive, and judicial bodies, the relationship between them is different from that in the US. The government agencies involved in this study in a Chinese context generally refer to the people's congresses as legislatures, executive bodies, and judicial bodies, such as procuratorates and courts, or all public agencies with food safety risk management functions, which constitute the government agency system for food safety risk management. This study aims to investigate the cross-boundary collaboration between government agencies for food safety risk management in China.
- 2 This study does not examine the relationship between food safety risk management and the effectiveness of public-public collaboration, nor does it investigate the method or governance effectiveness of public-public collaboration. Instead, it aims to assess the main factors affecting collaboration among food safety regulators in China. It does not investigate social co-governance by the government, society, and market, nor does it examine the effects of prevention, risk management, and whole-process control on food safety risk management.
- 3 The government agencies discussed in this study are government organizations with legal personality and an independent organizational system. The Food Safety Committee of the State Council of China with a subordinate office was established in February 2010 to coordinate public-public collaboration. As an organization directly under the State Council, the Office of the Food Safety Commission had clear responsibilities and dedicated staffing and funds to perform the routine work of the Committee. However, this Office, which had an independent organizational system, was abolished and turned into a dummy organization during another reform by the State Council to form the China Food and Drug Administration in March 2013. Since then, it is no longer an organization directly under the State Council, nor a component of the government agency system for food safety risk management. Therefore, the Food Safety Commission of the State Council and its office are not within the scope of this study.
- 4 Different countries have different conditions and governance systems. Joint regulation by multiple government agencies for food safety management is currently adopted by most countries. Nevertheless, this study does not discuss the relationship between regulatory model (number of government regulators) and governance effectiveness.
- 5 Interested readers may request data on the distribution of grassroots staff in food safety regulation in China from the corresponding author.
- 6 According to Massy (1965), Liu et al. (2003), and Roberts and Whited (2013), conclusions obtained by PCA do not require robustness checks. Nevertheless, the

robustness of conclusions of this study was tested and verified by replacing the variables and including control variables.

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Author contributions

LW, LZ, and YL jointly conceptualized the research study, planned the data collection and analysis, and interpreted data. LZ conducted data collection and data analysis, and drafted the initial manuscript. LW provided oversight and contributed to writing the manuscript. YL provided suggestions on data analysis.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was received from the Ethics Committee of Jiangnan University. The study was conducted according to the guidelines of the Personal Information Protection Law of the People's Republic of China.

Informed consent

Informed consent was obtained from all subjects involved in the study. All participants provided informed consent after having the study described to them before data collection activities. All data were collected, processed, and analyzed anonymously.

Additional information

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