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EDITED BY

Qingli Dong,
University of Shanghai for Science and
Technology, China

REVIEWED BY

Cidonea Deponti,
Universidade de Santa Cruz do Sul, Brazil
Zengjin Liu,
Shanghai Academy of Agricultural
Sciences, China

*CORRESPONDENCE

Xiaonan Fan
✉ fanxiaonan@dlpu.edu.cn

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Evolution and comparison of food safety governance in China—based on DTM model

Jiayi Wang, Xiaonan Fan* and Minghua Dai

School of Management, Dalian Polytechnic University, Dalian, China

Scientific and effective food safety governance policies can regulate the activities of food producers and enhance consumers' confidence in food safety, which are the cornerstone of social harmony and stable development. The existing research has focused on the policy content, hot topics, and the application of policy tools, but has lacked the dynamic tracking of food safety governance policies and ignored the investigation of the causal mechanism between policy tools and governance effectiveness. Based on the Dynamic Topic Model (DTM), this research systematically examines the evolutionary pathways, phase-specific features of food safety governance policies in China, and the correlation mechanism with governance effectiveness as well. By collecting and analyzing 675 national policy documents from 1979 to 2024 in China, the policy evolution is divided into three main stages, including Experiential Regulation and Legalization Exploration Stage, Legal Restructuring and Institutional Strengthening Stage, and Smart Governance and Collaborative Co-governance Stage. The findings show that: (a) A total of 15 hot topics of food safety governance policies are identified, which include market supervision, production process regulation, national standards and food additives, inspection and testing technologies, and catering service safety, etc. (b) In terms of horizontal analysis, China's food safety governance policy has established a comprehensive governance framework by clarifying the responsibilities of various levels of institutions, strengthening full-chain supervision, setting up demonstration projects and special inspections, and implementing regular risk monitoring. (c) In the longitudinal analysis, the evolution of China's food safety governance policies has gradually shifted from single supervision, export orientation and accident response to multi-party governance, internal and external coordination and risk prevention, which reflects the continuous improvement of the legalization, coordination and intelligence of China's food safety governance policies. The evolution analysis of food safety governance policy topics is of great significance for optimizing the regulatory system, enhancing governance efficiency, and safeguarding public health.

KEYWORDS

food safety governance, text mining, topic evolution, DTM, policy evolution

1 Introduction

People regard food as their prime need, but food safety comes first. Food safety directly affects public health and is a persistent global health challenge (Nayak and Jespersen, 2022; Shen et al., 2023). According to data from the World Health Organization (WHO) in 2023, 600 million people worldwide fall ill each year due to consuming contaminated food, resulting in 420,000 premature deaths. In recent years, despite the continuous

improvement of China's food safety governance system, problems such as food fraud, improper use of food additives and safety risks in campus canteens still exist (Downing et al., 2017). The report of the 20th CPC National Congress clearly put forward the strategic deployment of "strengthening the supervision of food and drug safety", highlighting the critical role of food safety governance in the national governance system. Currently, countries worldwide have established their own distinctive food safety governance systems, in which government-led policy frameworks consistently play a key guiding role.

The choice of government policy tools and the effectiveness of their application directly affect the degree to which governance goals are achieved. In the era of digital governance, government websites serve as important platforms for disclosing government affairs information, delivering online services, and facilitating government-citizen interaction, which carry a large amount of key information such as policy documents, regulations and systems, plans and programs etc. The information is not only an authentic record of the governance process, but also provides abundant primary sources for policy analysis. This methodology integrates multidisciplinary approaches—including content analysis, statistical inference, and bibliometrics—to analyze both the intrinsic content characteristics and extrinsic attributes of policy documents quantitatively. It objectively reveals the preferences for policy tools, the evolutionary trends of policy themes, and the collaboration patterns among policy actors (Huang et al., 2015), thereby providing a scientific basis for policy evaluation and optimization (Huang et al., 2018). Scholarly research has carried out in-depth explorations in multiple fields such as new energy industry policies (Li et al., 2025), financial policies (Wang, 2024), health insurance policies (Farchi and Salge, 2017), and medical policies (Ledoux et al., 2018). On the one hand, based on the external attributes of policy texts, the temporal characteristics of policy issuance and the distribution patterns of the agencies are examined. On the other hand, based on the content of policy texts, the deployments of policy tools and thematic evolution trends are investigated.

This research takes food safety governance policies as the research object and uses the websites of various departments of the central government of China as the data source to systematically collect and integrate national-level food safety governance policy documents from 1979 to 2024. By using visualization and policy evolution analysis, this research explores the development trends and features of China's food safety governance policies, offering insights for improving the food safety governance system. The main innovation points include: (1) This research applies the DTM to analyze the evolution of food safety governance policy themes, examines the horizontal interactions of policy themes in the same period and identifies the vertical evolutionary pathways of themes at different stages. The findings are visualized with Sankey diagrams, revealing the dynamic evolution of food safety governance policy themes over time. And it illustrates how China's food safety regulatory system has transitioned from a single-sector supervision to a multi-stakeholder co-governance, how the policy focus has shifted from incident response to risk prevention, and how the governance pattern has evolved from an export-oriented framework to a system emphasizing both domestic and international coordination. (2) This research categorizes China's

food safety governance into three distinct phases according to regulatory frameworks, landmark events, and risk profiles, basing on the policy documents issued with the enactment and revision of laws and regulations as benchmarks. And the thematic distribution and policy priorities in each phase are examined.

2 Literature review

2.1 Research on food safety governance policies

Food safety has become a core social issue of common concern worldwide. Governments of various countries have successively introduced corresponding laws and regulations to strengthen food safety governance (Telesetsky, 2020). Food safety governance refers to the process in which multiple participants such as the government, enterprises, and social organizations formulate and implement rules, policies, and measures to ensure food safety. These measures aim to effectively manage and control food safety issues across all stages, from production and processing to distribution and consumption (Dong and Qi, 2025).

In recent years, many scholars have conducted research on food safety governance policies, mainly in the following research directions: In the perspective of policy changes, scholars have analyzed the process and characteristics of the changes. Huang and Zhao (2020) used the discontinuous equilibrium theory to analyze the changing process of China's food safety policies and the existing inherent limitations, providing a reference for the reform and optimization of food safety supervision policies. Wang and Su (2018) divided the evolution of China's food safety policies into four stages. Based on the divided stages, they analyzed the changing characteristics of different stages and summarized the experience of solving China's food safety problems. Jiang and Feng (2024) analyzed the process of changes in China's food safety supervision system and found that the government has developed a pendulum-like policy adjustment model in response to risks and challenges. The government, through repeated adjustments between campaign-style governance and conventional governance, continuously identifies problems, analyzes them and explores through trial and error to find solutions and promote the improvement of conventional mechanisms. From the perspective of governance subjects, scholars explore the model of joint governance by multiple subjects (Garcia Martinez et al., 2007; Zanella et al., 2018). Wu et al. (2021) emphasized the significance of the joint participation of the government, the market, and society in the governance effectiveness evaluation of food safety risk governance policy tools in China, and analyze the role of three types of policy tools in social co-governance: mandatory, guided and voluntary.

2.2 Research methods on food safety governance policies

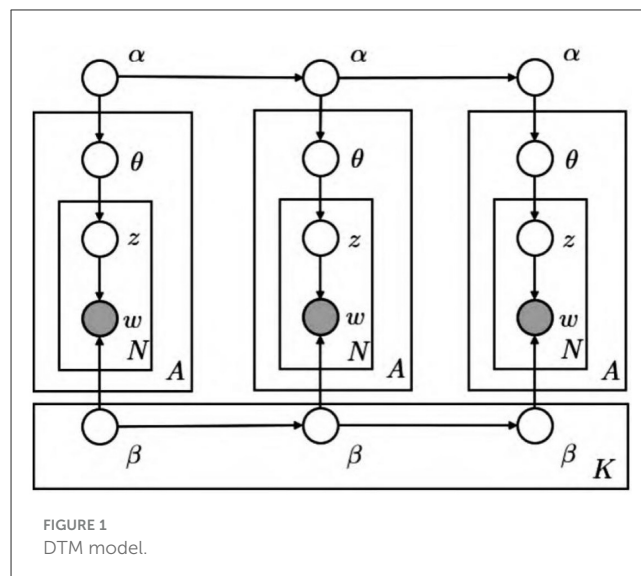
The research methods of food safety governance policies focus on policy content analysis and policy tool analysis. From the perspective of policy content analysis, Song et al. (2022) used the

LDA topic model and the K-Means clustering method to analyze the content and hot topics of food safety policies, and conducted a quantitative analysis of China's food safety policies. They conducted research from the perspective of policy tools. Policy tools refer to the intervention measures taken by the government to address key issues in economic or social development or to correct market failures (Kern and Howlett, 2009). Xu and Tian (2021) analyzed the driving forces behind the selection of food safety policy tools from the decision-making logic of rationality and social interaction. Based on the theoretical framework of effectiveness-acceptability, the selection mode of policy tools is divided into four categories, and the category characteristics and changing trends of policy tool selection in food safety governance are summarized. Wu and Chen (2024) analyzed the evolution logic of policy tools in the process of food safety risk governance in China and Western countries from the perspective of the emergence and evolution trajectory of policy tools for government governance of public social affairs.

2.3 Research on the DTM model

To explore the dynamic evolution process of the topic and the evolution of topic popularity, some scholars choose the DTM model for in-depth mining. The Dynamic Topic Model (DTM) is developed based on the LDA model. It is based on the time series, slices the document set by time, and simulates the dynamic evolution of the topics by analyzing the differences in text topics at adjacent time points. With the rapid development of Internet technology and the remarkable progress of computer technology, DTM analysis has been widely applied in fields such as economics, finance, and sociology (Shen et al., 2019). Wu et al. (2023) used the DTM model to quantitatively analyze 60 US artificial intelligence strategy reports, and the stage strategic focus and theme evolution trends of the US artificial intelligence strategy were explored from the time dimension. Relevant experiences were summarized to optimize the development strategy and planning in the field of artificial intelligence in China. Gao et al. (2022) adopted the DTM model for topic modeling, and combined with the knowledge graph, conducted a quantitative literature study on the topic evolution and policy changes of community governance policies in China was conducted.

To sum up, the existing research has focused on the policy content, hot topics, and the application of policy tools, but has lacked the dynamic tracking of food safety governance policies and ignored the investigation of the causal mechanism between policy tools and governance effectiveness. Therefore, this research uses the dynamic topic model (DTM), topic popularity and similarity calculation methods to conduct a systematic analysis of China's food safety governance policies. It delves deeply into the evolution laws of food safety governance policy themes, analyzes the impact of policy tools on food safety governance, and provides new research perspectives and empirical evidence for improving China's food safety governance system.



3 Research design

3.1 Research methods

3.1.1 DTM

The Dynamic Topic Model (DTM) is an extension of the Latent Dirichlet Allocation (LDA) model and is proposed based on the LDA model (Blei and Lafferty, 2006). DTM belongs to the category of generative models and is capable of analyzing the dynamic process and evolution law of topics in the document collection over time (Han et al., 2021). Specifically, DTM cuts the text data into multiple time segments and assumes that the documents within each time segment follow the topic model of the same dimension. However, the topic distribution and vocabulary distribution of each time segment change over time. DTM uses the topic and vocabulary distribution of the previous time segment to predict the topic and vocabulary distribution of the next time segment, constructing a dynamic topic evolution process. This process effectively supplements the limitation that the LDA model can only model static texts and improves the research on the dynamic evolution of text analysis methods. Its detailed principle can be referred to in Figure 1.

In the figure, K represents the number of topics, A represents the number of documents within the time slice, N represents the number of words in the documents, z and w represent the final generated topics and topic words, α and β represent the Dirichlet prior distribution parameters, α is the possible topic distribution for each document, β is the possible word distribution for each topic, and θ is the topic model of the document. It indicates obedience to a Dirichlet distribution with the parameter α. At time t, the topic distribution of the literature α_t and the word distribution under the topic β_{t,k} both depend on α_{T-1} and β_{T-1,k} at the previous time, and the dependency relationship is obtained through a simple dynamic model.

3.1.2 Topic popularity calculation

The support index is mainly used to reveal the characteristics of the topic popularity, reflecting the attention of the topic in a certain period of time. Through the DTM model, we obtain a document-topic matrix that indicates each document's probability of belonging to certain topics (Qiu et al., 2023). The formula for calculating topic popularity using the support index is as follows:

$$TIK_{(t)} = \frac{Dock_{(t)}}{Doc_{(t)}} \quad (1)$$

$TIK_{(t)}$ represents the popularity of topic k under the current time segment t . The denominator indicates the number of all documents under the current time segment t , and the numerator indicates the number of supported documents of topic k under the current time segment t . $TIK_{(t)}$ larger the value, the higher the popularity of the topic.

3.1.3 Topic similarity calculation

Topic similarity represents the degree of similarity between documents. The similarity can be achieved by calculating the probability distribution of topics corresponding to the documents (Wang et al., 2013). In this research, we employ the Hellinger distance function from the gensim library to calculate inter-stage topic similarity. Sankey diagrams are then generated based on similarity scores to visualize the evolutionary pathways of topics in China's food safety governance policies.

3.2 Research framework

Based on the DTM model, this research analyzed China's food safety governance policy texts by examining term collocations, concept transitions, and keywords. The research identified and refined hot topics in food safety governance, while tracing the evolutionary trajectory to reveal characteristic patterns and trends in policy development. The research framework is shown in Figure 2.

4 Data acquisition and preprocessing

4.1 Data collecting for food safety governance policies

The research selects China's food safety governance policies as the research object. Firstly, Python was used to retrieve, acquire and download the policy documents related to "food safety" from official government portals, including the Central People's Government website (<http://www.gov.cn>). Subsequent searches were conducted on relevant ministerial and departmental websites to ensure comprehensive coverage and data integrity. Finally, the collection yielded 758 national-level laws and regulations, among which 675 remain currently valid and enforceable.

4.2 Stages of policy development

This research categorizes China's food safety governance into three distinct phases based on policy documents issued during different economic periods. The phases is demarcated by the enactment and revision of laws and regulations, while also considering corresponding regulatory systems, landmark events, and characteristic risk patterns. According to the food safety policy documents issued in different economic periods in China, marked by the formulation and adjustment of laws and regulations, the governance of food safety in China is divided into three stages based on regulatory systems, typical events and risk characteristics.

The first stage: Experiential Regulation and Legalization Exploration Stage (1979–2007).

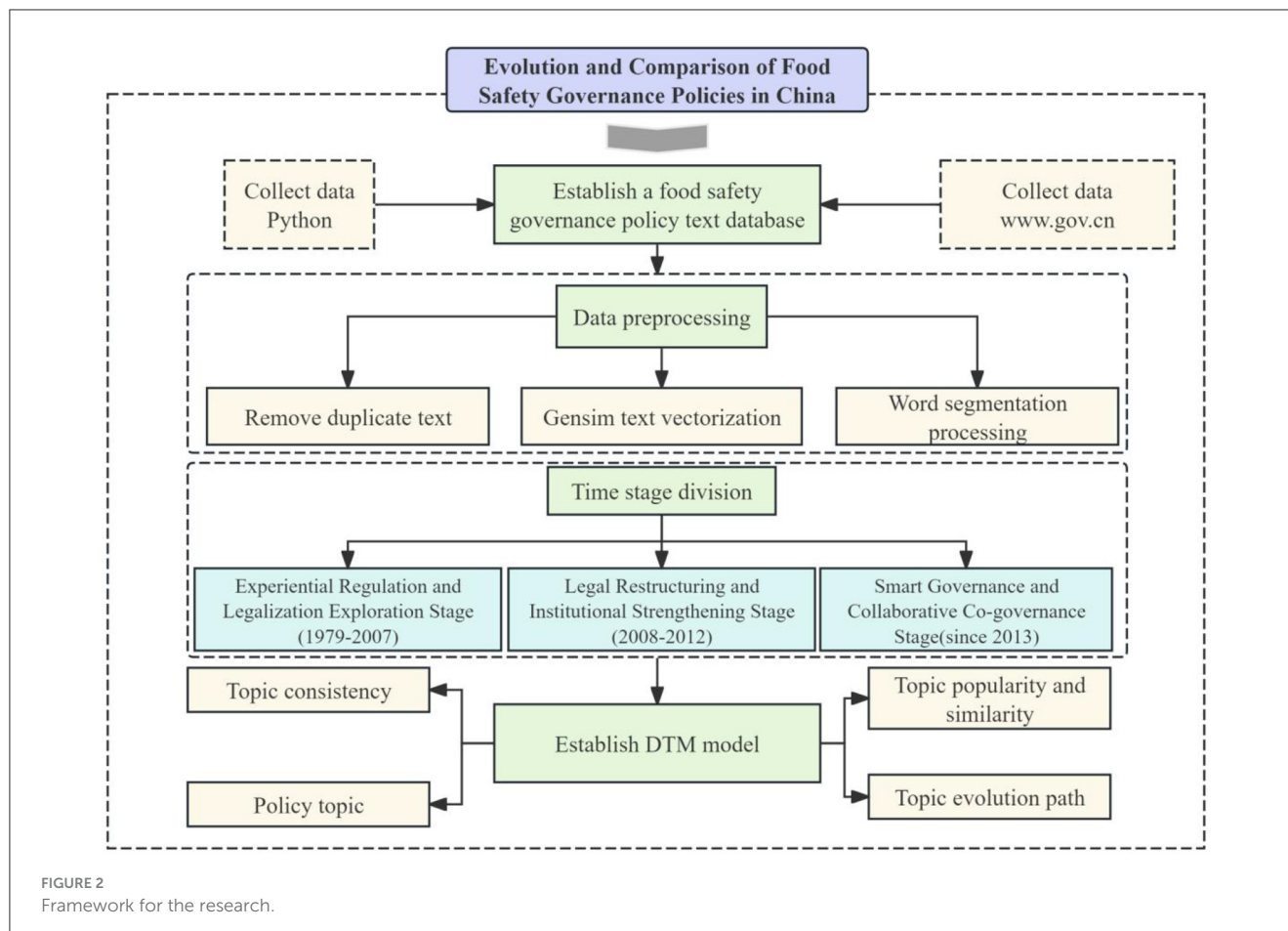
During this period, China successively enacted the Food Hygiene Management Regulations, the Food Hygiene Law (Trial), and the Food Hygiene Law, gradually establishing a single-regulator system centered on health authorities, with legal empowerment for food hygiene supervision and enforcement (Guo et al., 2019). In 2004, the "Decision on Further Strengthening Food Safety Work" became the first State Council document to formalize a "segmented regulation" model. In 2006, the Agricultural Product Quality Safety Law was promulgated, establishing 62 pesticide residue limits and laying a regulatory foundation for source control.

Meanwhile, the 1996 UK mad cow disease outbreak (with global repercussions) and subsequent food safety scandals eroded public trust, exposing dual governance failures of "market failure" and "government failure." This pressured authorities to incorporate societal actors in risk governance. High-profile incidents—including China's 2001 clenbuterol poisoning, 2004 Fuyang inferior infant formula scandal, and 2003 SARS crisis—revealed systemic flaws: ambiguous legal liabilities, inadequate penalties, and interagency coordination failures, prompting legal revisions and institutional reforms. Notably, 32% of dairy enterprises remained unlicensed before the 2007 Sanlu melamine scandal, highlighting regulatory gaps and systemic fragility.

In summary, under the institutional background of the transition from a planned economy to a market economy, China's food safety governance has undergone a gradual transformation from "administrative control" to "legal standardization": the regulatory system has transitioned from single administrative dominance to multi-departmental segmented supervision, the construction of regulations has evolved from extensive to detailed, and regulatory measures have extended from post-event penalties to source prevention and control. However, institutional development lagged behind industrial expansion, manifesting a reactive "crisis-driven policy patching" approach. Persistent challenges—including overlapping mandates, inconsistent standards, and coverage gaps—underscored the immature governance framework.

The second stage: Legal Restructuring and Institutional Strengthening Stage (2008–2012).

The 2008 melamine-tainted milk scandal starkly exposed systemic deficiencies in China's food safety oversight, particularly the ambiguous responsibilities and coordination failures stemming from multi-agency segmented regulation, marking a pivotal turning point for regulatory restructuring. In 2009, the Food



Safety Law superseded the Food Hygiene Law, legally defining “food safety” for the first time and establishing a “division of labor with unified coordination” principle. This created a five-ministry regulatory framework involving the Ministry of Agriculture and CFDA (China Food and Drug Administration) for staged supervision. In 2010, the State Council elevated governance by establishing the Food Safety Commission (FSC) as a high-level coordinating body, replacing the Ministry of Health’s leading role. The concurrent creation of the FSC Office launched targeted campaigns against gutter oil and dairy safety issues, enhancing interdepartmental collaboration. The “12th Five-Year Plan for the National Food Safety Supervision System” released in the same year further promoted the institutionalization of the supervision system. Meanwhile, online rumors in the field of food safety began to emerge. Simultaneously, food safety-related online rumors emerged as new challenges. The 2011 Weibo panic over “iodized salt preventing nuclear radiation” triggered nationwide hoarding, revealing acute information asymmetry, public panic, and lagging government response capabilities (Ju and Ye, 2018).

In general, China’s food safety governance during this stage was characterized by a tripartite upgrade of “regulations-institutions-standards”, marking a conceptual shift from “food hygiene” to “food safety”. The regulatory structure evolved from the Ministry of Health’s unilateral leadership to a segmented, multi-department model under the high-level coordination of the State Council’s Food Safety Commission, while the legal framework achieved completeness through supplementary legislation. Although

administrative enforcement was strengthened and standard systems improved during this period, regulatory processes still lacked standardization (Pei et al., 2011). Moreover, the rise of online media has further intensified the complexity and dynamics of food safety governance. The government still needs to continuously strengthen the construction of monitoring and early warning mechanisms and improve the transparency of information disclosure. Strengthen communication and interaction with the public and build a social co-governance pattern for food safety.

The third stage: Smart Governance and Collaborative Co-governance Stage (2013 to present).

China comprehensively revised the Food Safety Law in 2013 and implemented it in 2015, establishing the basic principles of “prevention first, risk management, full-process control, and social co-governance”. For the first time, new business forms such as online food trading, health food, and infant formula food were included in the regulation. In the same year, Fonterra dairy products from New Zealand were recalled globally due to the detection of dicyanide residues and potential botulinum contamination, which prompted China to accelerate the construction of a food safety traceability system. In 2014, Guangdong took the lead in establishing an electronic traceability system for infant formula milk powder. In 2017, Shanghai launched a digital traceability platform for school lunches. By 2018, JD Logistics had achieved a technological breakthrough in cross-border cold chain management by joining the Global Blockchain Freight Alliance. In terms of regulatory system reform, the

establishment of the State Administration for Market Regulation in 2018 marked a shift from “segmented supervision” to “unified supervision throughout the entire chain”. The implementation of new regulatory tools such as “dual randomization and public disclosure” has significantly enhanced law enforcement efficiency. The promulgation of 12 supporting regulations including the “Regulations on the Implementation of the Food Safety Law” in 2019 marked a strategic transformation of the legislative system from filling gaps to improving quality.

At this stage, China’s food safety governance has achieved a paradigm transformation from “single supervision” to “comprehensive governance”: in terms of the regulatory framework, it has shifted from multi-department segmented supervision to overall coordination by the State Administration for Market Regulation. In terms of governance tools, it has expanded from traditional administrative inspections to a multi-party co-governance model. In terms of technical approaches, it has been upgraded from traditional spot checks to a three-dimensional prevention and control system that combines smart tools such as blockchain traceability. During this process, the pass rate of food sampling inspections rose from 94.6% in 2013 to 99.2% in 2024, and the risk classification control, full traceability and emergency response mechanisms were gradually improved.

4.3 Data preprocessing

Obtain the policy text and clean it up. Use Python web crawlers to obtain policy texts and information data from government websites such as the Chinese Government website. Crawl policy texts containing keywords such as “food safety” in the full policy text, manually remove policies with a lower correlation to “food safety”, remove irrelevant content such as blank Spaces, punctuation marks, numbers, and English characters in the text, and only retain Chinese characters. Obtain the cleaned policy information resources and text data.

4.3.1 Text preprocessing

Convert the cleaned text data into text data of a unified format in the order of the fields of title, release date and main text. Then, the data is processed by word segmentation, cleaning, time series slicing, etc., to generate subject words with timestamps. The Jieba library is used to segment the text. Through natural language processing methods such as the TF-IDF algorithm, adding custom dictionaries, and removing stop words, the text is de-stopped, that is, common function words and words with no actual meaning in the text are removed. Combined with the Chinese stop word list (the stop word list of Harbin Institute of Technology), the accuracy of words related to food safety is guaranteed. Meanwhile, time window segmentation is carried out to obtain words with time series characteristics and related to food safety.

4.3.2 Word frequency filtering

Topic modeling mainly calculates the distribution of “word - topic” and “topic - document”. Low-frequency words and high-frequency meaningless words can greatly reduce the operational

efficiency of the model and the interpretability of the results. In this research, the word frequencies of the processed words will be statistically analyzed, and these words will be deleted before conducting DTM modeling.

4.3.3 Text vectorization

Text vectorization refers to the process of converting text into numerical values to facilitate calculation and analysis. In this research, the corpora module in the gensim library is used. Referring to the approach of Li et al. (2022), based on the bag-of-words model, the text after word segmentation is represented as a word frequency vector to prepare for the analysis of the DTM model.

4.4 The optimal number of topics is determined

Determining the optimal number of topics is foundational for topic extraction. We employed Gensim’s Coherence Model to calculate topic-word distribution coherence scores for each time period, using the mean value as the overall coherence metric. Theme consistency measures the semantic relatedness of words within a topic. Prior research indicates that higher coherence scores correspond to better topic model performance, improved topic interpretability, and stronger internal consistency (Guan and Wang, 2016; Stevens et al., 2012; Mimno et al., 2011). In this research, the optimal number of topics for the DTM model is determined by calculating the theme consistency of different topic numbers in three stages. Higher consistency is taken as the evaluation criterion, and the optimal number of topics in each time window dataset is combined to balance the interpretability of the topics. The consistency score results of the food safety governance policy themes are shown in Figure 3 below. When the number of topics is 15, the average value of theme consistency among the three stages is the highest. Therefore, the research sets the number of topics to 15.

5 Evolution and comparison of China’s food safety governance policies

5.1 Horizontal analysis of topics

By training the DTM model with text data from different stages, we obtained the “topic-word matrix” and word weights of food safety governance policies at each stage, allowing us to categorize specific topics based on high-weight words within each topic. This research identified 15 latent topics, and for each topic, we selected the 10 words with the highest average weights across all periods as the keywords representing that topic. The key words of China’s food safety governance policies are shown in Table 1.

According to Table 1, China’s food safety governance policies have established a comprehensive framework through clearly defining institutional responsibilities at all levels, strengthening

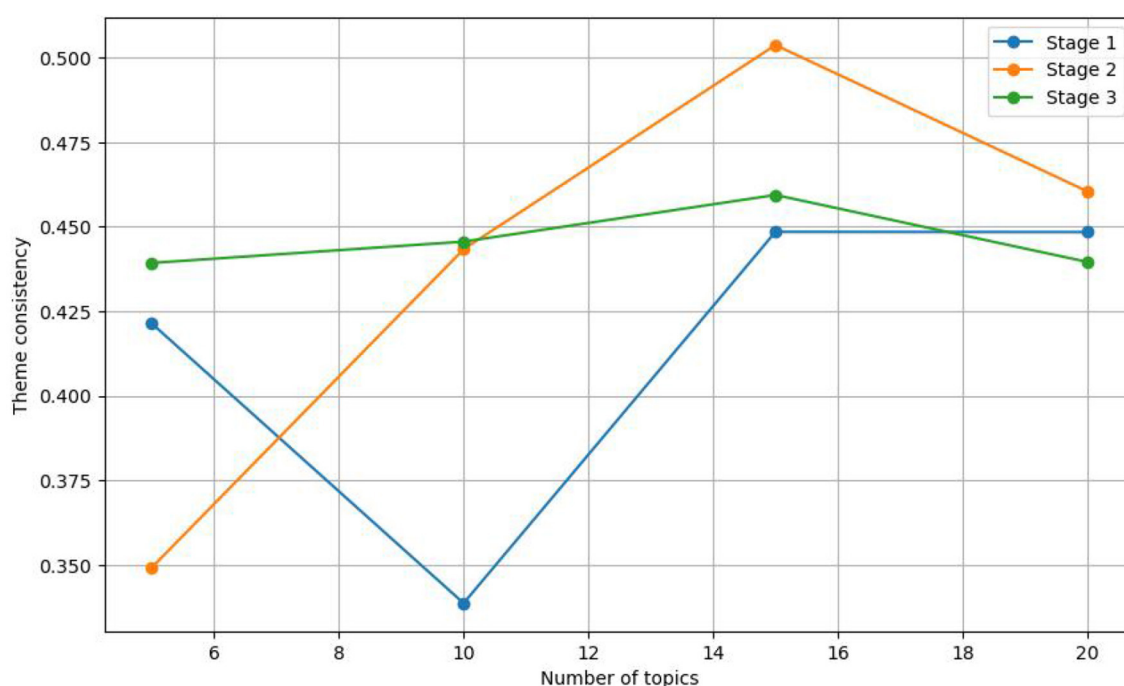


FIGURE 3
Theme consistency.

whole-chain supervision, implementing demonstration projects and special inspections, and conducting routine risk monitoring. Firstly, in terms of the governance subjects and the division of responsibilities, the specific duties of various institutions from the central to local levels, such as the Drug Administration (Topic 1) and the Inspection center, in areas like market supervision (Topic 0), catering hygiene (Topic 4), and standard setting (Topic 11), thereby providing organizational safeguards for effective regulation. Secondly, in terms of processes and technologies, the policy system covers segments from production sources to end users: including safety production oversight and inspection in the production process (Topic 2), standardized management of national standards and food additives (Topic 3), standardized application of inspection and testing technologies (Topic 5), traceability management of product exports (Topic 6), catering service safety (Topic 7), and implementation of technical regulatory measures (Topic 9). The system also emphasizes review procedures and process standardization, such as re-check process (Topic 10). Next, in terms of policy goals and implementation strategies, the policies not only set up a demonstration creation project to enhance the overall level (Topic 8), but also address prominent issues through special inspection and rectification actions (Topic 12), and conducts inspection and investigation after an accident occurs (Topic 13). Finally, potential risks should be detected and warned of in a timely manner through regular risk monitoring (Topic 14). These measures together form a comprehensive governance framework, which is conducive to ensuring food safety and safeguarding public health.

5.2 Analysis of topic popularity

To reflect the focus of food safety governance policies at different stages, this research calculates the topic popularity of each topic in the three stages based on Formula (1), and presents the topic popularity in a heat map, as shown in Figure 4.

5.2.1 Experiential regulation and legalization exploration stage

During empirical regulation and legalization exploration stage of food safety governance policies, China focused on developing fundamental institutional frameworks and functional regulatory capacities. Combining the analysis of topic phase heatmap, product export traceability, inspection technology, and institutional functions were the key points of this stage, with their topic heat levels reaching as high as 0.619, 0.066, and 0.048 respectively. The topic of national standards and food additives also maintained relatively high popularity.

Specifically, the central policy objective during this stage was addressing international compliance pressures on food safety under globalized trade, as China, being a major food exporter, needed to strengthen whole-chain supervision of exported foods through traceability systems to meet international standards (e.g., ISO 22000) and enhance global market trust. The traceability systems during this period were primarily driven by administrative mandates, reflecting the government-dominated governance model, while testing technologies and

TABLE 1 Chinese food safety governance policy topics.

Number	Topic	Words
0	Market supervision	Sampling qualified Market Cold-chain Food Commerce Department Products Logistics Commerce Supervision
1	Medical and health policy	Health Restoratives Medical equipment Medical Monitor Health key 2030 Institutions
2	Production process regulation	Food Food Safety Produce Supervision and administration Inspect Management Sale Safe accident Government Production operators
3	National standards and food additives	Food Safety Food National standards GB Additives Product Announcement Attachments 2014 Hygiene
4	Supervision of catering units	Food Safety Food Catering Unit Drug administration Hygiene Food and drug Propagate Supervisor Organization
5	Inspection technology	GB Inspect Food Sample Project Product Sampling Food Safety National standard Detection
6	Product export traceability	Produce Record Food Inspect Product Export Traceability Central office Amount Area
7	Catering service safety	Food Food Safety Catering School Processing Disinfection Canteen Unit Facility Inspection
8	Demonstration creation project	Demonstration Supermarket Establish City Premade Agricultural product Edible Minister Oats Safe meat
9	Technical supervision measures	Food Food Safety Key point Management Safety supervision Supervisor Produce Central office Implement Link
10	Recheck process	Inspect Food Organization Sample Recheck Sample Code Administrative area Administrator Safety supervision
11	Institutional function	Food Food Safety Committee member Inspect Center Council Research institute Prevent Disease Formulate
12	Special inspection	renovate Produce Food Sale Special project Product quality Inspect Check Export Quarantine
13	Accident survey	Food GB additive Case Accident Residual amount Epidemiology Incidence Sampling Inspect
14	Risk monitoring	Sample Monitor Organization Food Safety Spot check Food and drug Inspect Pb Central office Inspected

institutional functions played supporting roles - the former not yet established as an independent policy tool but mainly employing sensory evaluation and physical property analysis for export certification purposes, and the latter mainly involving division of labor and coordination between customs and quality supervision departments without forming an effective cross-departmental collaboration mechanism. Although national standards and additives were not the central focus, their relatively high popularity indicated policymakers' growing awareness of the importance of standardization systems.

5.2.2 Legal restructuring and institutional strengthening stage

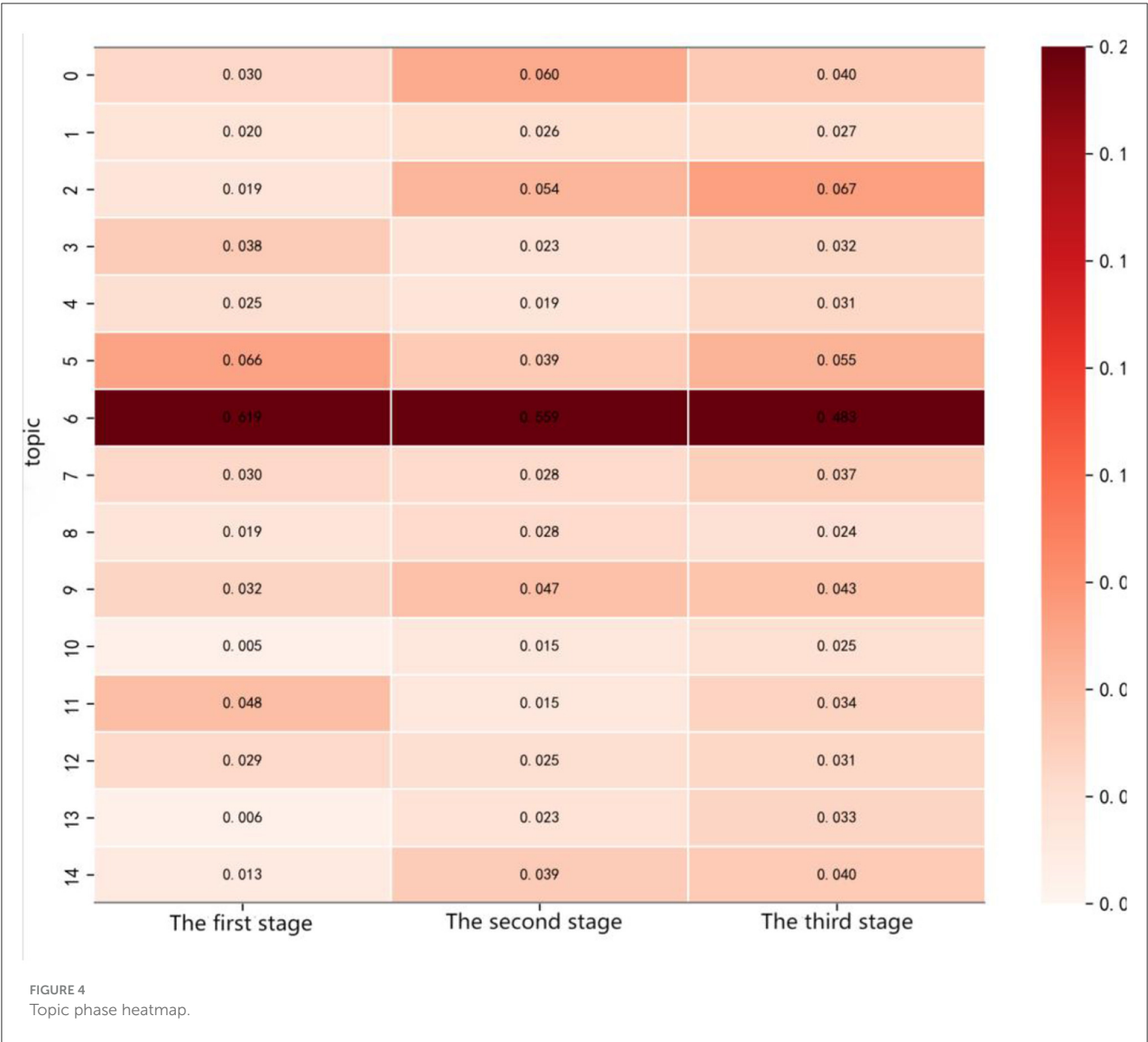
With the revision and implementation of the Food Safety Law, policy governance has entered a Legal Restructuring and Institutional Strengthening Stage. Based on the analysis of topic popularity, product export traceability, market supervision, and production process regulation were the focuses of this stage, with their topic popularity reaching as high as 0.559, 0.060, and 0.054 respectively. Technical regulatory measures also had a relatively high popularity.

Specifically, the governance system during this phase shifted from being export-oriented to emphasizing both domestic and international markets, with innovative technologies beginning to be applied though detection capabilities still lagged behind regulatory demands. Although the popularity of product export traceability

decreased somewhat, it remained the top priority, indicating the preliminary institutionalization of export supervision systems, where the National Health Commission took charge of comprehensive coordination and organizing investigations into food safety incidents, while policy focus expanded into deeper areas of the domestic market. The prominence of market supervision and production process regulation significantly advanced the standardized construction of food safety oversight, the development of integrity self-discipline systems for food operators, the enhancement of regulatory enforcement capabilities, and the establishment of long-term management mechanisms. The improvement in technical regulatory measures reflected an innovative trend in policy tools, with internet technologies like big data and blockchain beginning to be applied in traceability systems such as China's Traceability Platform, though their use remained limited to information recording functions without yet achieving advanced capabilities like risk early warning. However, the relative decline in the popularity of testing technologies exposed systemic shortcomings where detection capacities failed to keep pace with the expansion of regulatory scope, revealing issues such as uneven distribution of grassroots testing resources.

5.2.3 Smart governance and collaborative co-governance stage

During the stage of smart governance and collaborative co-governance of food safety governance policies, China's policy



evolution had shown significant characteristics of refinement and specialization. Based on the analysis of topic popularity, product export traceability, production process supervision, and inspection technology were the focuses of this stage, with their topic popularity rates reaching as high as 0.483, 0.067, and 0.055 respectively. Technical regulatory measures also had a relatively high level of popularity.

The policy evolution at this stage exhibited dual characteristics of technological innovation and collaborative deepening: on one hand, it strengthened whole-chain food safety supervision by transforming functions from compliance certification to quality empowerment; on the other hand, it achieved synergy between testing technologies and technical regulatory measures, shifting regulatory efficacy toward preventive approaches through innovations like rapid detection technologies. Although export traceability’s popularity declined to 0.483, its continued dominance indicates this mechanism has become deeply embedded in the governance system while evolving from “compliance certification”

to “quality empowerment.” The rise in production process regulation’s popularity (0.067) reflects a policy shift from end-product control to process management. The recovery of testing technologies’ popularity (0.055) and their synergy with technical regulatory measures signify technological tools’ upgrade from “supporting means” to “core drivers,” where widespread adoption of rapid testing and molecular traceability technologies has transformed regulatory effectiveness from “post-incident handling” to “preventive intervention”, substantially enhancing whole-chain supervision through collaborative governance.

5.3 Analysis of the evolution path of topics

To simplify the evolution path of topics, this research first screens out low-heat topics before calculating the similarity of topics. Through experiments, it is found that setting the heat

threshold at 0.025 yields better results. Then, filtering is conducted based on a similarity threshold of 0.3 (Yang et al., 2022). Finally, the Sankey diagram of the topic evolution path in China's food safety governance policies is drawn, as shown in Figure 5.

5.3.1 From single regulation to multi-party governance: the improvement and integration of the regulatory system

China's food safety governance policies have gradually transitioned from the early decentralized supervision and export compliance orientation to a systematic and domestic demand-oriented regulatory model. This reflects the transformation of policies from single supervision to multi-party governance, the continuous enhancement of coordination and integrity, as well as the emphasis on improving domestic market supervision capabilities. Early market supervision (Topic 0) focused on basic functions. With the establishment of the Food Safety Law, it formed a collaborative mechanism with product export traceability (Topic 6) whereby exported food had to pass domestic market sampling inspections before entering international markets, ultimately transitioning toward specialized domestic supervision. National standards and food additives (Topic 3), serving as the technical foundation, initially supported export food compliance with international standards before shifting to develop a standards system tailored to domestic industries. Supervision of catering units (Topic 4) shifts from basic supervision to scenario-based fine management, with a focus on strengthening high-frequency scenarios such as school canteens and online catering, and the direct connection with export traceability is weakened. Production process regulation (Topic 2), as the core of source control, achieved rigorous supervision through continuous legal improvements covering raw material procurement, hygienic production process control, and finished product inspection to ensure food safety at the production origin.

5.3.2 From export-oriented to internal and external synergy: technological upgrading and governance system improvement

The evolution of China's food safety governance policies reflects a process from export-oriented to collaborative integration, and then to regular functional configuration, ultimately forming a functional configuration logic that prioritizes regular supervision and supplements it with specialized supervision. It reflects the transformation from technological upgrading driven by export demand to the improvement of the domestic governance system, demonstrating the policy's response to phased demands and its maintenance of the overall governance system's supporting capacity.

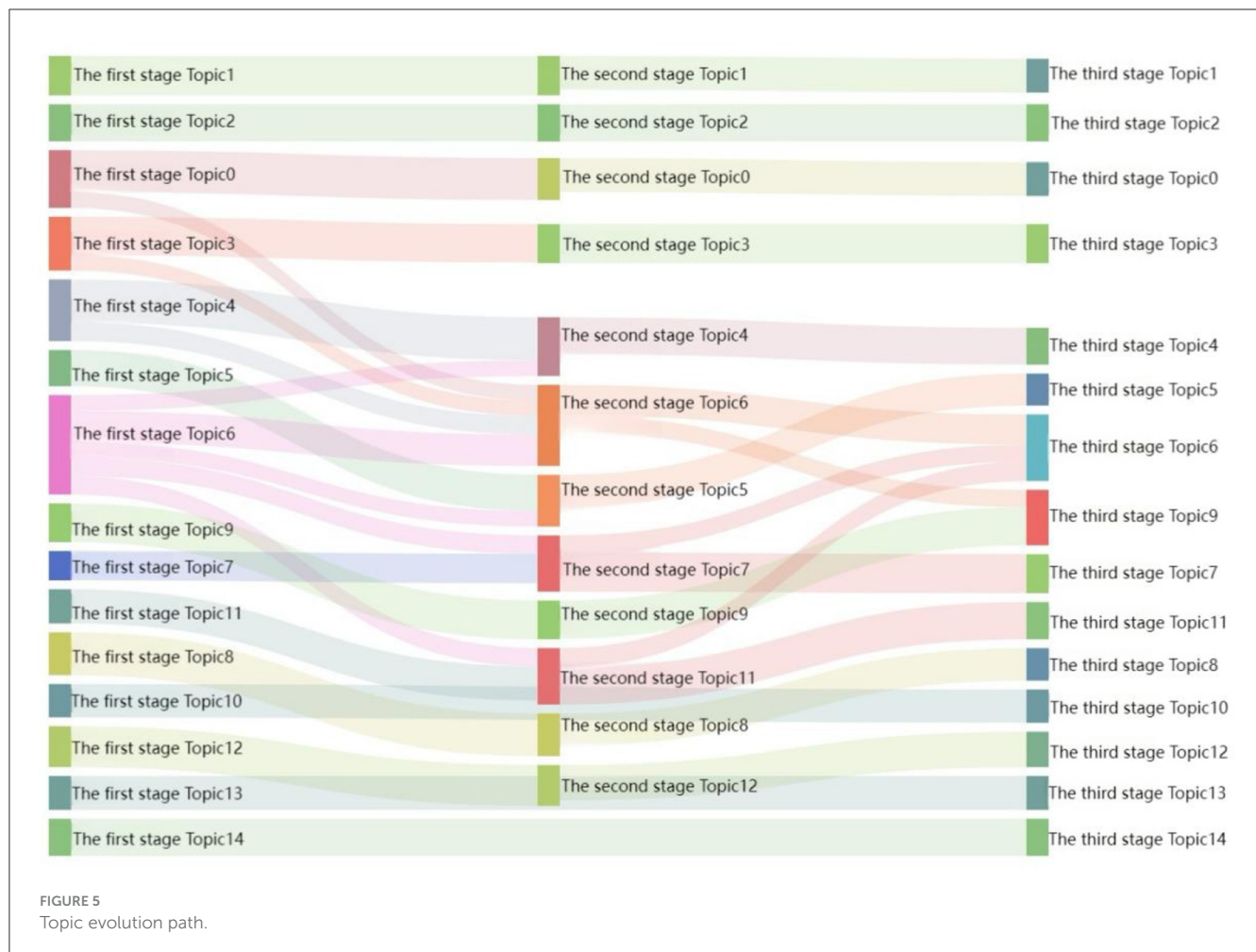
Product export traceability (Topic 6) demonstrated its core role at the early stage of policy evolution. Its information and management requirements have permeated multiple dimensions such as the supervision of catering units (Topic 4), inspection technology (Topic 5), catering service safety (Topic 7), and institutional functions (Topic 11). This not only indicates that the management of exported food has had a significant impact on multiple domestic links. It also reflects the trend of coordinated

development between export traceability and domestic supervision. Topics such as market supervision (Topic 0), national standards and food additives (Topic 3), and supervision of catering units (Topic 4) also provide data and normative support for the export traceability system. Subsequently, the deep integration of the export traceability system with technical supervision measures (Topic 9), through the application of technologies such as blockchain and big data to achieve full-process visual tracking, marks a transformation in the governance of export food from the establishment of a basic framework to quality improvement and efficiency enhancement. Inspection technology (Topic 5) was initially driven by export demand, facilitating alignment with international standards. Subsequently, it shifted to serving the domestic full-chain supervision, demonstrating the collaborative application of technology in the dual circulation at home and abroad. Technical supervision measures (Topic 9) initially focused on key links such as production and operation. Later, with the development of food export trade, export demand gradually promoted domestic technological upgrading and regulatory optimization. Driven by the traceability of exported food, technical regulatory measures were strengthened and widely applied throughout the entire traceability process, enhancing the competitiveness and safety of exported food. Institutional functions (Topic 11) changed in the early stage due to the need for cross-institutional collaboration in export food traceability, involving multiple links and requiring functional connection and data sharing among multiple departments. With the maturation of the export food traceability system, the marginal demand for cross-institutional collaboration has declined, and the functions of various institutions have gradually returned to the normal configuration covering the entire domestic chain of supervision.

5.3.3 From accident response to risk prevention: strengthening the food safety defense line

China's food safety governance policies have gradually shifted toward collaborative whole-chain management, strengthening the construction of risk monitoring and early warning prevention and control systems, promoting the standardization and efficiency of inspection and testing technologies, facilitating the transformation from accident inspection to precise traceability, and expanding the dimensions of risk monitoring. In addition, the policy has also guided collaborative cooperation and data sharing among multiple institutions to build an integrated regulatory network, achieving a policy transformation from passive response to accidents to proactive risk prevention and control.

From the perspective of the development of China's food safety governance policies, early governance focused on foundational management with relatively fragmented approaches, where medical and health policy (Topic 1), demonstration creation project (Topic 8), and special inspections (Topic 12) demonstrated a certain degree of independence. With the increase in risks and the maturation of the governance system, the content of medical and health policies has gradually been integrated into the collaborative system such as risk monitoring. The demonstration creation project has evolved into a regular regulatory standard, and special inspections have been incorporated into the regular



regulatory mechanism. The demand for the entire chain of “post-event inspection (accident inspection)-process standardization (re-inspection process)-preevent warning (risk monitoring)” has become prominent. Accident survey (Topic 13), recheck process (Topic 10), and risk monitoring (Topic 14) are directly connected to the third stage across the second stage, reflecting the iterative upgrade of the inspection and testing as well as risk prevention and control system in the process of policy evolution. With the popularization of detection technologies (such as mass spectrometry and chromatography) and the development of information technology (big data risk early warning platforms), the re-inspection process places greater emphasis on standardization and efficiency. Accident inspection has shifted toward precise traceability (such as the application of genetic traceability technology in the investigation of foodborne diseases), and risk monitoring has expanded to multi-dimensional data collection (covering the environment, food components, etc.). The policy guidance on the application of technology has been continuously strengthened. Moreover, under the impetus of policies, the collaborative mechanism among multiple institutions such as inspection agencies, disease prevention and control centers, and market supervision departments has been continuously improved. Risk monitoring data, re-inspection processes, and

accident inspections support the cross-departmental food safety risk supervision mechanism, facilitating the construction of an integrated supervision network. The policy has extended from a single “accident handling” to “risk monitoring-early warning and prevention-re-inspection and verification-accident source tracing”.

6 Conclusion and limitations

This research divides China’s food safety governance policies into three stages: Experiential Regulation and Legalization Exploration Stage, Legal Restructuring and Institutional Strengthening Stage and Smart Governance and Collaborative Co-governance Stage. Through the DTM model, we quantitatively analyzed the national-level food safety policy texts and divided them into 15 major topics. Based on the summary and analysis of these topics, we analyzed the key points of food safety in China at different stages and systematically reveals the dynamic evolution characteristics of China’s food safety governance policies.

The research finds that the evolution of China’s food safety policies shows a significant transformation: the regulatory

system has shifted from single supervision to multi-party co-governance, the management focus has changed from accident response to risk prevention, and the governance model has shifted from export-oriented to internal and external coordination, which reflects the continuous improvement of the legalization, coordination and intelligence of China's food safety governance policies. China continuously improves food safety regulations and standards and strengthens food quality inspection. By leveraging technologies such as Internet, big data, and blockchain, a full-process traceability system for food safety should be established to enhance the modernization level of inspection and testing technologies, optimize grassroots testing institutions, and improve professional regulatory capabilities. We will increase investment in food safety testing technology and equipment, build an information sharing platform for regulatory authorities, and establish a joint law enforcement mechanism. Meanwhile, by establishing a co-governance pattern for food safety, the diversification and socialization of food safety governance have been achieved.

Despite its contributions, this research has several limitations. Firstly, relying solely on the policy text data on national-level food safety themes released on government websites may lead to a single source of data, making it impossible to obtain all policy documents in the field of food safety. Future research could incorporate local policy analysis to examine central-local government dynamics in policy diffusion and implementation, thereby providing a more comprehensive assessment of China's food safety governance framework. Secondly, the demarcation of policy time periods should adopt a more objective and precise methodological approach rather than manual division, so as to minimize researchers' subjective influence. Finally, while the DTM model can effectively identify thematic patterns and evolutionary trends in policy texts, it remains limited in uncovering the underlying drivers behind policy formulation. Moreover, the interpretation of model outputs may involve subjectivity influenced by researchers' expertise. Future researches should integrate complementary quantitative and qualitative methods—such as policy network analysis and case studies—to gain deeper insights into the complex factors shaping policy development and implementation processes.

Against the backdrop of globalization, food safety has emerged as a top-priority issue for governments worldwide, characterized by institutional standardization, end-to-end regulatory oversight, technology-driven empowerment, and stringent enforcement mechanisms. Japan has established exceptionally stringent maximum limits for contaminants, microorganisms, and food additives in food products. The country employs cutting-edge information technologies to build agricultural product traceability systems, achieving traceability accuracy rates as high as 99%. Furthermore, Japan regularly updates its food safety testing standards to ensure alignment with the latest international scientific advancements and food safety regulations. Finland adheres to the “One Health” principle, enforcing strict farm-to-table food safety controls through comprehensive preventive measures at the production source. Germany implements full-chain supervision from agricultural production to processing

and distribution, maintaining pesticide residues in vegetables at microgram-level concentrations. Singapore's Food Safety and Security Act (FSSA) imposes severe penalties including heavy fines and imprisonment for violations. These international best practices offer valuable insights for China to further advance its food safety governance reforms. In the future, China should continue to deepen the reform of food safety governance, enhance scientific and technological innovation, strengthen the social co-governance mechanism, and improve the construction of laws and regulations. In terms of technological application, we should constantly explore the application of new technologies in food safety supervision. In terms of the social co-governance mechanism, we should encourage all sectors of society to widely participate in food safety governance and improve the pattern of joint participation by the government, enterprises, consumers and other parties. In terms of laws and regulations, we should further improve its food safety laws, regulations and standard systems, strengthen penalties for violations, raise market access thresholds, and enhance supervision over all stages of food production, processing and distribution to ensure public food safety.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

JW: Visualization, Data curation, Writing – review & editing, Methodology, Writing – original draft. XF: Data curation, Writing – review & editing, Conceptualization, Methodology. MD: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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