

Exploring Pathways to Effective Government Public Health Governance: — A Fuzzy Set Qualitative Comparative Analysis of 31 Provinces

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Abstract. This study examines the factors influencing government performance in public health governance and how different combinations of these factors drive outcomes. By integrating the Technology-Organization-Environment (TOE) theory and resource-based theory, researchers utilize fuzzy set qualitative comparative analysis (fsQCA) to explore the multiple pathways to governance performance in major public health events across 31 provincial-level regions in China. The findings reveal three pathways to achieving high governance performance, which are Environment-Driven Pathway, Technology-Driven Pathway, Resource-Light Technology-Driven Pathway. The Technology-Driven pathway plays a crucial role in enhancing governance performance, and multiple equivalent combinations contribute to improved outcomes. Furthermore, government attention is identified as a key factor in achieving high governance performance in public health.

Keywords: TOE theory, resource-based theory, public health governance performance, fuzzy set qualitative comparative analysis.

1. Introduction

In recent years, the world has frequently faced significant public health events, including infectious diseases such as the COVID-19 pandemic, Ebola virus, Zika virus, and mpox. These incidents have not only tested governments' emergency response capabilities but also revealed numerous weaknesses in public health systems, including poor communication, uneven resource distribution, and inadequate grassroots prevention efforts. In this context, effective public health governance is crucial for social stability and economic development, making the enhancement of governance capacity particularly important. The 1988 report *The Future of Public Health* by the Institute of Medicine (IOM) defines public health governance as "the process by which society makes decisions, plans, and allocates resources to coordinate various stakeholders to promote and protect the health of the population" [1]. This definition clearly outlines the core elements and objectives of public health governance, which are to ensure the health of the entire population. This goal underscores the significance of health issues and serves as a direct test of the government's public health governance capabilities. However, current governmental efforts in public health governance face several challenges, including ineffective policy implementation, insufficient resource allocation, and inadequate regulatory mechanisms. The complexity of these tasks necessitates that governments develop efficient, coordinated, and intelligent public health governance capabilities to address increasingly complex and diverse health challenges.

The performance evaluation in public health can be traced back to 1995 when the U.S. Department of Health and Human Services (HHS), guided by the Government Performance and Results Act, advocated for public health performance evaluation research. It defined performance evaluation as "a quantitative indicator system for tracking the extent to which programs achieve their objectives, or for monitoring changes over time through program implementation". In the domain of government public health governance performance assessment, Donabedian's [2] structure-process-outcome triad stands as a seminal framework. This model posits that in public health programs, structure encompasses infrastructure and resource allocation, process refers to the specific steps of service

delivery, and outcome measures the actual health impacts on populations, thereby offering a systematic evaluation framework for public health governance.

U.S. scholarship has advanced both theoretical frameworks and measurement tools for public health governance performance evaluation. Notable achievements include the Conceptual Model of Public Health Systems and the National Public Health Performance Standards (NPHPS). The former emphasizes interorganizational collaboration between governmental and non-governmental entities within public health systems and underscores the role of policy formulation in shaping performance outcomes, establishing a conceptual framework for public health performance mechanisms [3]. The latter delineates 10 essential public health services covering core functions such as assessment, policy development, and assurance, aiming to enhance the operational capacities of public health agencies across government tiers [4]. This framework extends the traditional "input-output-impact" paradigm through its performance-oriented design.

The United Kingdom, exemplifying a National Health Service (NHS) system, introduced the Balanced Scorecard approach in 1999, formalizing the NHS Performance Assessment Framework (PAF). This framework prioritizes efficiency while advocating for polycentric governance and multi-stakeholder collaboration [5]. Subsequent iterations saw local health authorities develop performance indicators to monitor regional service delivery. Australia, since the 1990s, has institutionalized the National Health Performance Framework (NHPF), structured around three dimensions: health status and outcomes, determinants of health, and health system performance. This framework facilitates systematic monitoring and management of healthcare system efficacy [6]. These pioneering frameworks offer valuable insights for global public health governance.

In China, performance evaluation in public health emerged in the 1990s and remains in its nascent exploratory phase. Current scholarship spans multiple facets of governance performance assessment, including public health expenditure efficiency [7, 8], disease prevention and control performance [9, 10], and public health service system performance [11-13]. While some regional governments and institutions have developed localized performance evaluation tools, these initiatives often lack robust theoretical foundations, rigorous reliability/validity testing, and multidimensional scope, with evaluations predominantly confined to subnational levels [4, 14].

To refine assessment frameworks and better diagnose governance challenges, Chinese scholars have shifted focus toward identifying critical determinants of performance. For instance, Song et al. (2012) identified interagency collaboration and healthcare workforce capacity as pivotal factors influencing governance efficacy [15], highlighting the importance of cross-sectoral coordination and human capital. Deng et al. [16] further emphasized that synergistic mechanisms between governmental tiers and health systems could optimize resource allocation and performance outcomes, underscoring institutional coordination as a governance linchpin. These studies adopt a holistic perspective to analyze factors affecting policy implementation and health impacts.

Despite these advancements, research on government public health governance remains underdeveloped. Prevailing studies predominantly rely on qualitative descriptions and anecdotal evidence, with limited empirical analyses. Moreover, existing scholarship often examines isolated factors at technical, organizational, or environmental levels, neglecting the conjunctural effects of multifactorial interactions that underlie heterogeneous governance performance.

To investigate the complex causal mechanisms behind high public health governance performance and to understand how multiple interacting factors generate different combinations that influence government public health governance, we draw upon the TOE framework and resource-based theory. This study examines three dimensions: technology, resources, and environment. Using fuzzy set qualitative comparative analysis, the study aims to identify both diverse and combinatorial pathways. These findings are significant for modernizing government public health governance and enhancing the quality of life for citizens.

2. Literature Review and Research Framework

2.1. TOE Theory

The TOE (Technology-Organization-Environment) theory proposed by Tornatzky and Fleischer [17] has exerted extensive academic influence. The essence of the TOE theory lies in providing a multi-level analytical perspective to understand how technologies are adopted and implemented within specific organizational and environmental contexts [18]. It consists of three core components: First, the technological context, which involves internal and external technological resources of enterprises, including existing technologies, emerging technologies in the market, and their characteristics. Specifically, this dimension focuses on technological attributes, capabilities, advancements, and uncertainties [19, 20]. Second, the organizational context, which primarily concerns internal characteristics and resources of enterprises that determine their capacity to adopt and implement new technologies. This includes organizational size and structure, resource endowments, organizational culture, top management support, and implementation readiness [21, 22]. Third, the environmental context, which emphasizes external factors such as political, economic, and social conditions surrounding organizations [23].

The TOE theory has been widely utilized in fields such as government governance and public health. In government governance, it has been applied to analyze performance differences and improvement pathways across various dimensions, including local government website development, data collaboration in public service governance, and online government service capabilities. Research indicates that local governments can effectively enhance website construction through controllable factors like technological management capacity and attention allocation [22]. Moreover, the TOE framework has been used to identify pathways for improving data collaboration in public service governance, suggesting that provincial governments should adopt context-specific strategies [24]. In the public health sector, the TOE framework also plays a crucial role. Studies demonstrate that it aids in understanding how to enhance public health governance performance in ethnically diverse regions, revealing the interactive effects among technological, organizational, and environmental factors. This theoretical framework offers a comprehensive perspective for analyzing and clarifying the influencing pathways of government public health governance performance, establishing it as the logical foundation for our research [25].

2.2. Resource-Based Theory

The Resource-Based Theory (RBT) traces its origins to Penrose's 1959 seminal work *The Theory of the Growth of the Firm*, which established the theoretical foundation for the resource-based view by elucidating the relationship between corporate resources and organizational growth. Wernerfelt's 1984 article "A Resource-Based View of the Firm" formally introduced the resource-based perspective, marking the theory's inception. From the traditional RBT lens, firms are conceptualized as bundles of unique and heterogeneous resources. This theory posits that sustained competitive advantage stems from four core resource attributes: value, rarity, inimitability, and non-substitutability [26]. The theory has evolved through three developmental phases—traditional resource-based view → dynamic resource-based view → resource orchestration perspective—as evidenced by contemporary scholarship [27]. Resource heterogeneity constitutes a fundamental premise of RBT. Scholars diverge in defining and categorizing resources. For instance, Barney [26] classified corporate resources into three types: physical capital, human capital, and organizational capital. Bao [28] integrated organizational capabilities within resource constructs, whereas Xiang [29] delineated capabilities as distinct from resources. Dollinger [30] further proposed six resource categories: financial, physical, technological, human, organizational, and reputational. Such conceptual diversity implies that managerial interpretations of resources critically influence both resource deployment strategies and organizational performance trajectories. Consequently, applying

RBT to enhance performance necessitates rigorous consideration of resource multidimensionality and complexity.

Resource-based theory has emerged as a key theoretical foundation for research in government and public health governance. Some studies have formulated analytical frameworks based on this theory to assess how combinations of resource factors influence the performance of digital government initiatives, emphasizing that internal resource conditions and the ability to manage these resources are crucial for achieving a competitive advantage [31]. In the context of comprehensive intelligent governance, resource-based theory is used to explore how to convert resource endowments into governance strengths [32]. This underscores the importance of effective resource allocation and management for enhancing governance efficiency during transformational processes. Furthermore, resource-based theory plays a critical role in the allocation of public health resources, with research highlighting that this allocation is a vital component of healthcare systems, in which the government holds a leading role [33]. From this theoretical perspective, we gain valuable insights into how the government can improve the efficiency and equity of public health services by strategically allocating human, financial, and material resources.

2.3. Research Progress on Factors Influencing Government Public Health Governance Performance

The academic community has made significant strides in exploring the factors that influence the public health governance performance of local governments. Scholars have introduced new perspectives mainly centered on organizational coordination and management capabilities, digital governance, and resource allocation.

First, organizational coordination and management capabilities significantly impact public health governance performance. Many scholars have explored the role of organizational management factors in public health governance, covering various aspects including organizational structure, management strategies, cross-departmental collaboration, and coordination mechanisms. These studies provide an important theoretical foundation and empirical support for understanding and enhancing public health governance performance. The diversity in organizational structures and working methods of local health departments may lead to differences in performance outcomes. For example, Lovelace [34] suggests that employing multidisciplinary top management teams (TMTs) can enhance institutional performance by integrating diverse expertise to tackle complex public health issues. However, the effectiveness of this structure also depends on its internal coordination and adaptability to external environments. Halverson et al. [35] emphasize that public health agencies must collaborate with external organizations to improve governance performance. This collaboration involves information sharing, influencing policy, communication, and coordination. They argue that effective governance requires close cooperation between government and non-governmental organizations to ensure equitable resource distribution and efficient public service delivery. Sun et al. [36] point out that deficiencies in public-private collaboration mechanisms, organizational management, and collaborative leadership systems may lead to performance losses in health projects. Through focus group discussions, Li and Feng [37] analyze the main factors affecting the service performance of county-level public health agencies, including insufficient government investment, inadequate interdepartmental coordination, low-quality health personnel, and underdeveloped management mechanisms.

Second, digital governance plays a crucial role in shaping public health governance performance. It utilizes modern information technologies, such as big data and artificial intelligence, to optimize governance models. The deep integration of big data with government governance can drive digital transformation in administrative processes, organizational structures, and functional modules, thereby constructing a vertically integrated and horizontally coordinated digital government. This facilitates the establishment of a novel governance operational paradigm characterized by administrative efficiency, online service delivery, and precision governance, ultimately enhancing governance efficacy and capabilities [38]. Specifically, the application of big data technologies in public health

governance has demonstrated robust monitoring and early warning capacities. For instance, by analyzing electronic health records, social media data, and wearable device information, public health departments can monitor disease transmission trends in real time and swiftly identify potential outbreaks, enabling timely preventive measures [39, 40]. Additionally, big data technologies can predict disease trends using machine learning algorithms, identify high-risk groups, and develop targeted intervention strategies [41]. Beyond monitoring and alerting, the transformative effect of big data in healthcare is particularly evident in public health policy formulation. By leveraging emerging data sources like Health Data Collaborative (HDC), big data can support the development of new diagnostics, therapies, and public health policies [42]. Tao et al. [43] conducted an empirical analysis of government public health governance performance across 47 prefecture-level cities in China, revealing that the advancement of big data technologies and the refinement of technological infrastructure can significantly enhance governmental capabilities in public health governance.

Third, the impact of resource allocation on government public health governance performance. The equity and efficiency of public health resource allocation directly affect the quality and accessibility of public health services. Regional variations in economic development levels and demographic structures impose distinct demands on resource allocation. For instance, rural areas suffer from inefficient resource allocation due to lower qualifications of health practitioners and outdated medical facilities, whereas urban regions face issues of excessive resource inputs [44]. To address these challenges, it is imperative to strengthen the responsibilities of governments at all tiers, particularly emphasizing the central government's role in public health governance, while optimizing resource allocation structures and enhancing utilization efficiency [8, 45]. Fiscal investment constitutes a core driver of public health governance, with fiscal transfer payments playing a pivotal role in mitigating regional disparities in public health services. Research indicates a negative correlation between fiscal transfer payments and the efficiency of healthcare resource allocation, suggesting that increasing fiscal transfer payments can incentivize local governments to augment health resource investments, thereby improving public health governance performance [46].

Currently, most studies focus on qualitative analyses and the accumulation of governance experiences related to specific public health emergencies, often lacking empirical data support. There is a pressing need to identify factors affecting public health governance through diverse empirical data. While some empirical research exists, it primarily concentrates on regression analyses of individual factors. Although this approach offers insights, public health governance is inherently comprehensive and collaborative, influenced by multiple driving factors. This perspective neglects the analysis of the synergistic effects of various influences. Therefore, we will conduct an in-depth study from a configurational perspective to identify the diverse pathways for enhancing provincial public health governance performance, clarifying the complex mechanisms by which different conditions affect governance outcomes [47].

2.4. Research Framework

This study seeks to integrate the TOE framework with resource-based theory to examine how technological, organizational, and environmental conditions collectively influence public health governance. By enriching the research perspective in this field, the findings aim to enhance government awareness of the capabilities and environmental factors affecting governance performance, ultimately aiding in the development of more effective strategies.

(1) Technological conditions: The deep integration of modern technology with national governance constitutes a vital force for innovating governance approaches and enhancing governance efficacy. Particularly in public health risk management, technological support is indispensable for surveillance, assessment, diagnosis, treatment, and research. First, professionals in the information technology sector provide foundational technical support for government public health governance performance. Through developing and applying advanced information technologies—such as electronic health records (EHRs), telemedicine, and mobile health applications—they can significantly improve the accessibility, efficiency, and practicality of healthcare services. Second, the

construction of digital infrastructure serves as the cornerstone for big data technologies to advance government public health governance. In the era of big data, as a critical resource, data plays a pivotal role in pandemic response. Enhancing data governance capabilities can effectively strengthen governments' capacity to address major public health emergencies [48]. The development of digital infrastructure is essential to realizing this capability. Public health institutions must invest in hardware, software, and network infrastructure to support the adoption and utilization of digital solutions.

(2) Resource conditions: This study posits that financial, human, and material resources—characterized by historical dependency, causal ambiguity, and social complexity—are valuable, scarce, and imperfectly imitable. These resources form the basis of organizational competitive advantages and play a critical role in improving public health governance performance. First, public health expenditure provides essential financial resources for government public health governance. China's fiscal decentralization system grants local governments greater fiscal autonomy, enabling them to increase public health spending based on local conditions, thereby enhancing the availability of regional medical resources and promoting public health outcomes [49]. Second, public health resources encompass human and material resources. These form the foundation of governance performance, ensure the proper functioning of administrative authority, and significantly influence governance capabilities [50]. For instance, according to the Implementation Plan for Further Improving the Fujian Provincial Healthcare Service System, Fujian Province significantly improved the equity and accessibility of healthcare services by increasing the number of health professionals and hospital beds.

(3) Environmental Conditions: Environmental factors focus on the influence of policy and societal dynamics. First, the attention and support from leadership shape the decision-making environment for government public health governance. Simon's bounded rationality theory posits that attention is a scarce resource that drives governmental decision-making. In the operational context of the Chinese government, the level of leadership attention exerts significant impacts on policy and project implementation [51]. Second, peer pressure affects the decision-making environment for public health governance, particularly evident in the competitive and mimetic behaviors among local governments. Under the "pressure-driven system," the central government exerts policy pressure through official documents to facilitate top-down policy diffusion. While sharing common pressures, local governments simultaneously experience peer pressure due to career advancement incentives and public opinion-driven political competition, leading to policy text modifications and accelerated policy diffusion [52]. In the process of digital public health governance, local governments often adopt convergent responses in policy transfer and technological alignment to comply with central directives [53]. Third, social participation shapes the societal atmosphere, thereby influencing the external environment of government public health governance. Studies demonstrate that citizen engagement can enhance administrative capacity, improve public service quality, and strengthen public trust in government, thereby promoting social stability [54].

3. Research Methodology

3.1. Fuzzy Set Qualitative Comparative Analysis (fsQCA)

This study utilizes fsQCA, a method introduced in 1987 by American sociologist Charles C. Ragin to investigate the multiple concurrent causal relationships among variables. fsQCA examines the relationship between antecedent conditions and outcomes from a set-theoretic perspective, helping to elucidate the complex mechanisms underlying various phenomena. Its unique feature is its ability to handle categorical issues, variations in degree, and partial membership. fsQCA has been widely applied across social research disciplines, including sociology, political science, and management. In the field of public health, there are numerous case studies employing fsQCA. For instance, Zhang and Li [55] selected 20 typical cases of social organizations participating in public health emergency prevention and control, employing the fsQCA method to investigate the impact of democratic

consultation on the performance of social organizations in emergency management. Hanckel [56] conducted a systematic review of QCA applications in public health, covering 27 papers and 26 studies on topics such as nutrition/obesity, physical activity, health disparities, and mental health.

The study selected this research method for several reasons. First, researchers considered the data characteristics of the sample, which include 31 provincial-level regions in China during 2022. The sample size is relatively small for regression-based quantitative analysis but somewhat large for qualitative analysis, making fsQCA suitable as it is designed for medium-sized samples, typically ranging from 15 to 80 cases. Second, fsQCA is particularly effective at addressing the complexity of causal relationships. Unlike traditional methods that focus on the impact of individual variables, governance performance during significant public health emergencies is a multifaceted issue influenced by various factors, such as technological conditions, social support, and government attention. Analyzing the net effect of a single independent variable on public health governance while controlling for others does not adequately capture the intricate causal mechanisms involved, which justifies our choice of this method. Finally, fsQCA offers significant advantages in identifying equivalent pathways, allowing researchers to explore different routes leading to the same or similar outcomes. This comparative nature enhances its potential value in responding to public health emergencies. For instance, in research on enhancing public health governance performance, fsQCA can help identify which factors constitute critical determinants of performance improvement across different regions or under varying conditional configurations. This method enables policymakers to comprehend the effectiveness of different pathways, thereby providing an evidence base for formulating more targeted and effective public health policies.

3.1.1 Conditional Variables

(1) Digital infrastructure: in March 2021, the Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through the Year 2035 was promulgated, proposing to "advance the coordinated development of traditional infrastructure and new-type infrastructure, establishing a modern infrastructure system characterized by systematic integration, high efficiency and practicality, smart and green technologies, as well as security and reliability. "the government's digital governance in public health relies on the digital hardware foundation in various provinces and cities. To assess this, researchers measure the state of digital infrastructure using the New Infrastructure Competitiveness Index of China, published by Tsinghua University's Internet Industry Research Institute in the report *New Infrastructure Competitiveness Index of China* (2023). This index includes three primary indicators: information infrastructure, integrated infrastructure, and innovation infrastructure.

(2) Technical support: information transmission, software, and IT services are vital areas for technological innovation, requiring high levels of technical expertise. Skilled professionals can leverage digital technologies to develop precise innovation strategies and mitigate associated risks [57]. Additionally, proficient R&D personnel can utilize these technologies to overcome technical bottlenecks and produce high-quality innovations. The development of these sectors typically involves significant R&D investments, making the proportion of personnel in these fields indicative of the region's technological innovation capacity. This proportion also reflects the scale of the digital industry in the region, further indicating its level of technical support. Data on this proportion is sourced from the *Statistical Yearbook of China* (2023).

(3) Financial resources: health funding positively influences residents' body mass index and self-rated health [58]. The report *Analysis of Government Health Investment in China since the 18th National Congress of the CPC* (April, 2019) indicates that local governments bear most of the financial responsibility for healthcare expenditures, with substantial disparities between central and local allocations. Per capita healthcare spending is generally higher in eastern and western regions compared to central regions. These regional financial disparities support the optimization of government health spending analysis across provinces. For financial resources, we will use the health

expenditures of provincial governments in 2022 as our measurement indicator, with data sourced from the *Statistical Yearbook of China* (2023).

(4) Public health resources: the level of health resources is typically measured by the number of health institutions, hospital beds, and health technicians per thousand people. These indicators reflect the organization, scale, and capacity of regional healthcare services, playing a foundational role in public health [59]. We will measure “the number of medical and health institution beds per thousand people” and “the number of health technicians per thousand people”, with data sourced from the *Statistical Yearbook of China* (2023).

(5) Peer pressure: competitive pressure drives governments to enhance public health governance performance, fostering a competitive atmosphere among regions. A specific measure of this pressure is the number of COVID-19-related policies enacted by neighboring provinces and a higher number indicates greater pressure. Data are sourced from the official government websites of these provinces. For example, Liaoning Province faces peer pressure from neighboring regions such as Beijing, Jilin, and Inner Mongolia.

(6) Government attention: Lu et al. [60] utilized provincial and municipal government work reports from 2010–2021 to measure the intensity and prioritization of governmental attention in environmental governance. This analytical method has measured government attention to environmental governance by analyzing provincial and municipal government work reports. This method reflects the volume of policy documents issued in specific areas, thereby gauging the level of concern. We adopt this approach by measuring the number of infectious disease prevention and control-related policy documents issued by provincial administrative units in 2022, with data sourced from their official websites.

(7) Level of social participation: the level of social participation assesses local residents' involvement and concern following significant public health events. Effective communication between residents and the government, often facilitated through media channels, is crucial for understanding residents' needs and responding appropriately to public health emergencies. Thus, local residents' participation is included in our analysis. The rise of social media and smart devices provides new data sources for public health governance. The Baidu Index has become a valuable resource for studying Chinese netizens' search behavior, reflecting social interest [61]. Dou et al. [62] utilized the Baidu Index platform as a data source to analyze societal attention toward the "Healthy China" initiative through keyword tracking. Adopting this methodology, we measure social participation levels via Baidu Index data, specifically operationalized by retrieving the daily average search volumes across regions for a composite set of keywords including: infectious disease prevention, vaccination, epidemic containment, influenza prevention, health literacy promotion, hand hygiene protocols, mask-wearing guidelines, home isolation requirements, public health policies, and health complaint hotlines. Higher daily average search volumes indicate elevated levels of social participation.

3.1.2 Outcome Variables

Government public health governance performance: American scholar Richard C. Kearney defines government performance as the results or achievements produced during the government's management of society. Based on this concept of government performance and following Tao et al.'s [43] measurement criteria for governance performance, government public health governance performance is measured through three indicators: "the ratio of the elderly population to the total regional population at the end of 2022," "regional birth rates in 2022," and "the ratio of uninfected population to the total regional population at the end of 2022."

Table 1. Variable Selection and Data Sources

Variable Names		Indicator Types	Data Source
Outcome Variables	Government Public Health Governance Performance	the ratio of the elderly population to the total regional population at the end of 2022, regional birth rates in 2022, and the ratio of uninfected population to the total regional population at the end of 2022.	<i>China Health Statistics Yearbook (2023)</i>
Conditional Variables	Digital Infrastructure	New Infrastructure Competitiveness Index of China	<i>New Infrastructure Competitiveness Index of China (2023)</i>
	Technical Support	Proportion of employees in information transmission, software, and IT services to the total provincial population	<i>Statistical Yearbook of China (2023)</i>
	Financial Resources	Government health expenditure by province	<i>Statistical Yearbook of China (2023)</i>
	Public Health Resources	Number of medical and health institution beds per thousand people	<i>Statistical Yearbook of China (2023)</i>
		Number of health technicians per thousand people	
	Peer Pressure	Number of policies introduced in neighboring provinces in 2022	Local Government Websites
	Government Attention	Number of policies issued by local governments in 2022	Local Government Websites
Level of Social Participation	Daily average of Baidu Index related to infectious disease prevention and control by region in 2022	Baidu Index	

4. Data Analysis

4.1. Data Calibration and Truth Table Construction

The calibration process entails converting raw measurement values into continuous numbers ranging from 0 to 1, which indicate the degree of membership of a variable within a specific set. This transformation aims to create fuzzy set membership scores that more accurately reflect the relationships between variables. This study utilizes three qualitative anchors for structured calibration: the full membership threshold (95%), the full non-membership threshold (5%), and the crossover point (50%).

4.2. Necessity Analysis of Single Variables

Before conducting a detailed analysis of the effectiveness of governance in major public health emergencies, the study first examined the necessity of each influencing factor individually. In fsQCA, necessity analysis determines whether a single condition is essential for an outcome to occur. This analysis is typically carried out through consistency testing. Schneider and Wagemann [63] state that a condition is deemed necessary if its consistency score exceeds 0.9. Researchers conducted a necessity analysis for each condition (including its negation), as shown in Table 2. The results from this analysis, based on Table 2, reveal that: first, the consistency scores for each condition are relatively high, indicating a certain degree of explanatory power regarding the outcome. Second, no

single condition achieved a consistency score above the threshold of 0.9, suggesting that no individual factor can independently serve as a necessary condition for high or low government public health governance performance. This finding highlights the complexity of managing major public health events, emphasizing the need for a coordinated approach that integrates technical, medical, policy, and social factors to achieve effective governance outcomes.

Table 2. Necessity Test for Univariate Analysis

Condition Variables	High Government Public Health Governance Performance		Low Government Public Health Governance Performance	
	Consistency	Coverage	Consistency	Coverage
Digital Infrastructure	0.700	0.542	0.656	0.742
~Digital Infrastructure	0.667	0.570	0.595	0.743
Technical Support	0.817	0.740	0.521	0.690
~Technical Support	0.658	0.485	0.804	0.865
Financial Resources	0.602	0.497	0.646	0.779
~Financial Resources	0.733	0.587	0.583	0.682
Public Health Resources	0.725	0.570	0.660	0.758
~Public Health Resources	0.693	0.583	0.626	0.768
Peer Pressure	0.567	0.470	0.647	0.783
~Peer Pressure	0.739	0.589	0.562	0.655
Government Attention	0.664	0.630	0.516	0.714
~Government Attention	0.698	0.497	0.733	0.761
Level of Social Participation	0.669	0.536	0.657	0.769
~Level of Social Participation	0.711	0.587	0.603	0.727

4.3. Sufficiency Analysis of Condition Configurations

Sufficient conditions refer to combinations of multiple factors that can lead to a specific outcome. In the fsQCA method, conducting sufficiency analysis requires establishing a consistency threshold and a frequency threshold. Schneider and Wagemann [63] recommend that the consistency level for determining sufficiency should not fall below 0.75. For small to medium-sized samples, the frequency threshold is typically set to 1, meaning only causal configurations that appear at least once in the dataset will be included in the analysis [64]. Given the sample size of 32, the study sets the case frequency threshold to 1 and the consistency threshold to 0.8. The intermediate solution in fsQCA is favored for its rationality and rigor, as it prevents the oversight of necessary conditions, demonstrates broad applicability, and retains stability in robustness checks. According to the intermediate solution (see Table 3), the overall coverage and consistency scores are 0.4974 and 0.894, respectively, indicating that all condition combinations explain approximately 50% of the cases and possess a strong explanatory power.

Table 3. Configurational Paths of Public Health Governance Performance

Outcome Variables	Condition Configuration	Raw Coverage	Unique Coverage	Consistency	Overall Solution Coverage	Overall Solution Consistency
y	$\sim X1 * X2 * \sim X3 * X5 * X6 * \sim X7$	0.352	0.151	0.910	0.497	0.894
	$\sim X1 * X2 * \sim X3 * \sim X4 * \sim X5 * \sim X6 * \sim X7$	0.306	0.097	0.883		
	$X1 * X2 * \sim X3 * X4 * \sim X5 * X6 * \sim X7$	0.208	0.022	0.885		
~y	$\sim X1 * \sim X2 * \sim X3 * X4 * \sim X6 * \sim X7$	0.383	0.031	0.960	0.637	0.933
	$\sim X1 * \sim X2 * \sim X4 * X5 * X6 * \sim X7$	0.289	0.017	0.970		
	$\sim X1 * \sim X2 * X3 * \sim X4 * \sim X5 * \sim X6 * X7$	0.235	0.026	1.000		
	$\sim X1 * \sim X2 * X3 * X4 * \sim X5 * X6 * \sim X7$	0.202	0.008	0.942		
	$\sim X1 * \sim X2 * \sim X3 * X5 * \sim X6 * \sim X7$	0.376	0.018	0.979		
	$X1 * X2 * X3 * X4 * X5 * X7$	0.268	0.018	0.944		
	$X1 * X3 * X4 * X5 * X6 * X7$	0.274	0.005	0.969		
	$X1 * X2 * X3 * \sim X4 * X5 * \sim X6 * X7$	0.314	0.033	1.000		

(For brevity, the results are represented as follows: X1 denotes digital infrastructure, X2 represents technical support, X3 indicates financial resources, X4 stands for public health resources, X5 signifies peer pressure, X6 represents government attention, and X7 denotes the level of social participation.)

4.4. Core Condition Analysis

The core condition analysis (see Table 4) identifies three driving paths that explain high levels of government public health governance performance, with each column representing a possible configuration of conditions. Specifically:

Configuration S1 indicates that in provinces where technological conditions are insufficient, an increase in government attention in response to strong peer pressure can lead to high public health governance outcomes. Here, technical support (technology) is the core condition, while peer pressure (environment) and government attention (environment) are marginal conditions. This path demonstrates that high government public health governance results depend on the interaction between technological advantages and favorable environmental conditions. Compared to S3, this path relies less on digital technology conditions and requires government attention as a driving force under high peer pressure. Since both peer pressure and government attention are environmental conditions, researchers designate this path as “environmentally driven.” This path accounts for approximately 35% of high-performance cases, with about 15% of cases attributable solely to this path.

Configuration S2 reveals that when provincial government personnel in information transmission, software, and information technology services are relatively high, there tends to be strong technical support, leading to high public health governance performance. This indicates that technical support (technology) is more crucial for achieving high performance than other conditions, as it can independently constitute a sufficient condition for the outcome. In this path, when technical support is present, other conditions become insignificant for high public health governance performance, so we label this path as “technologically driven.” This path explains approximately 31% of high public health governance performance cases, with about 10% of cases explainable solely through this path.

Configuration S3 illustrates that in situations where environmental conditions are insufficient, technological capabilities play a dominant role in improving public health governance performance under light resource constraints. In provinces with robust digital infrastructure and high technical support, increasing government attention and public health resource levels often lead to high public health governance outcomes. Here, technical support (technology) and government attention (environment) are core conditions, while public health resources (resources) are marginal conditions. In this path, due to the insufficient environmental conditions compared to S1, a certain level of public health resources is necessary alongside absolute reliance on technological advantages. Thus, this path is termed “technologically driven under light resource constraints.” This path accounts for approximately 21% of high-performance cases, with around 2% of cases explainable solely through this path.

Table 4. Analysis of Core Conditions

Antecedent Conditions	High Government Public Health Governance Performance		
	S1	S2	S3
Digital Infrastructure	⊗	⊗	●
Technical Support	●	●	●
Financial Resources	⊗	⊗	⊗
Public Health Resources		⊗	●
Peer Pressure	●	⊗	⊗
Government Attention	●	⊗	●
Level of Social Participation	⊗	⊗	⊗
Consistency	0.910	0.883	0.885
Raw Coverage/%	0.352	0.306	0.208
Unique Coverage/%	0.151	0.097	0.022
Overall Consistency/%	0.894		
Overall Coverage/%	0.497		

Note: ● denotes the presence of core conditions, ● denotes the presence of marginal conditions, ⊗ denotes the absence of core conditions, ⊗ denotes the absence of marginal conditions, and a blank space indicates the non-existence of the condition.

Condition Configuration 1: Resource-Driven. This configuration explains cases from provinces such as Jilin, Heilongjiang, Inner Mongolia, and Tibet. Jilin province is a notable example, actively promoting a transformation in digital government management by establishing a “province-wide coordination and city-based utilization” model. According to the 2023 assessment report on integrated public service capabilities released by the National Academy of Administration, Jilin’s capabilities ranked in the “very high” category in 2022. As a traditional industrial base, Jilin also has a solid foundation in technical capacity. The province has significantly increased its investment in major public health services, indicating a growing governmental commitment to public health governance. Notably, Jilin faces competitive pressure in digital governance from neighboring regions, as the comprehensive indices of Liaoning, Inner Mongolia, and Heilongjiang exceed their own.

Condition Configuration 2: Technology-Driven. This configuration primarily explains the case of Hainan Province. In 2019, Hainan established China’s first provincial-level Big Data Management Bureau as a statutory entity. By 2022, Hainan ranked among the top ten provinces in the China Open Data Index, and the Hainan Provincial Government promulgated the Hainan Provincial Government Digital Transformation Master Plan (2022–2025), which established an "Five-Horizontal-Five-Vertical" governance framework, with prioritized development of two core platforms: "Haiyiban" (Convenient Governance Platform) and "Haizhengtong" (Government Collaboration Platform). By the end of that year, the “Hainan Government Connect” system achieved 100% coverage across all government departments. In building smart cities, Hainan has prioritized the development of integrated network communication infrastructure, enhancing its digital capacity. However, Hainan lacks advantages in both resources and environmental factors, which may be linked to its economic development level. Compared to the central and eastern regions, Hainan lags in both resource and environmental conditions. To improve public health governance performance in Hainan, it is essential to strengthen technical infrastructure and increase technical support.

Condition Configuration 3: Technologically Driven under Light Resource Constraints. This configuration primarily explains the case of Chongqing. The city has largely established a data resource system and foundational platform for smart healthcare development, achieving a leading position in China for data aggregation and standardization within its medical reform monitoring platform. Additionally, Chongqing has developed the “Health Cloud” online platform to enhance its intelligent response to public health emergencies. The “14th Five-Year Plan” for the healthcare service system in Chongqing (2021-2025) indicates that the city has built a comprehensive public health service system, covering disease prevention and control agencies, health supervision agencies,

and maternal and child health institutions across all districts. Chongqing has also strengthened its information systems for disease control to prevent major infectious disease outbreaks, establishing a citywide public health big data monitoring network. In 2021, the Chongqing Health Commission released the first provincial-level health information technology “14th Five-Year Plan”, aimed at promoting the deep integration of new technologies with healthcare services, highlighting the government’s strong commitment to public health governance.

4.5. Robustness Check

fsQCA is a set-theoretic method, and due to the subset relationships among the results, minor adjustments to the operational steps do not change the substantive interpretation of the original outcomes. This phenomenon is known as result robustness. Zhang and Du [64] systematically identified six variants of set-theoretic testing methods applicable to QCA (Qualitative Comparative Analysis), including adjustments to calibration thresholds, modifications to the frequency of case occurrences, the selection of consistency thresholds for differentiation, variation in the number of conditional variables, and the addition or removal of specific cases. By raising the consistency threshold from 0.8 to 0.85 in the fsQCA analysis, the paths in the intermediate solution remained consistent, confirming the robustness of the results. Therefore, the findings of the study are reliable.

5. Research Conclusions and Recommendations

5.1. Research Conclusions

Our study, grounded in the TOE framework and resource-based theory, analyzes public health governance among provincial governments in China, employing fsQCA for condition configuration analysis. We investigate the driving paths through which technology, resources, and environmental conditions impact local government public health governance performance. The research finds that first, technology, resources, and environmental conditions alone do not constitute necessary conditions for achieving high public health governance performance. However, these three types of conditions collectively form the driving paths for such performance: the environmentally-driven path, characterized by technical support, peer pressure, and government attention; the technologically driven path, focused solely on technical support; and the technologically-driven under light resource constraints path, which incorporates technical support, government attention, and public health resources. Notably, the technology-driven path plays a more significant role in enhancing public health governance levels. Second, the potential substitutive relationships among technology, resources, and environmental conditions indicate that under substantial peer pressure, peer pressure can effectively substitute for certain technological and environmental conditions, such as digital infrastructure and public health resources, thereby improving government public health governance performance through a “diverse paths, same outcome” approach. Third, technical support is essential for achieving high public health governance performance. In all three configuration paths, technical support emerges as a core condition and can independently serve as a sufficient condition for explaining the outcomes.

5.2. Policy Recommendations

First, public health governance requires a synergistic integration of technology, resources, and environmental factors. Local governments should develop policies tailored to their specific conditions, focusing on the interconnections among these elements from a holistic perspective. This localized approach will enable the creation of targeted and differentiated public health development pathways.

Second, enhancing technological conditions is essential for improving local government public health governance. This can be achieved by prioritizing the training of digital technology talent or attracting external digital experts to provide the necessary technical support for high-quality public health governance. Additionally, local governments should actively implement digital support

mechanisms and collaborate with high-tech companies to accelerate information flow and knowledge sharing through outsourcing and other strategies, fostering continuous innovation and enhancing governance. Prioritizing the development of digital infrastructure is also crucial to ensure the effective integration of digital technologies into governance processes.

Third, there is a potential substitutional relationship among technological, resource, and environmental conditions. Considering such relationships, government attention, being a controllable factor, can serve as a practical approach for local governments to overcome these constraints and rapidly improve public health governance performance. Therefore, in provincial regions significantly challenged by technological, resource, and environmental limitations, policymakers should focus on strategies to enhance government officials' awareness and attention to these critical issues.

5.3. Research Limitations and Future Directions

Our study has several limitations that warrant more in-depth and comprehensive investigations in future research.

First, while numerous factors influence public health governance performance, this research primarily adopts the TOE framework and resource-based theory. Due to data availability constraints, we focused on technological, organizational, and environmental dimensions. Future studies could incorporate broader determinants, such as socio-cultural dynamics or institutional innovation mechanisms.

Second, although the fuzzy-set Qualitative Comparative Analysis (fsQCA) identified critical configurations of factors affecting governance performance, this method remains a static analysis based on existing datasets. It inherently struggles to capture nuanced variations and underlying causal mechanisms in dynamic governance processes. To address this, future research should triangulate findings through mixed-method approaches—such as surveys, in-depth interviews, and field observations—to collect primary data. This would enable more direct and precise assessments of how digital empowerment shapes public health governance outcomes, thereby enriching empirical foundations and dynamic validations for configuration analyses under the TOE and resource-based theoretical frameworks.

Third, our dataset is confined to the year 2022, lacking longitudinal multi-year observations. This limits the explanatory power of conclusions across temporal dimensions. In the post-pandemic era, as regions undergo resource endowment restructuring, significant environmental shifts, and gradual socioeconomic recovery, whether the pathways driving high government public health governance performance exhibit new characteristics demands rigorous exploration. Future studies should extend the temporal scope to examine evolving governance patterns under emergent conditions.

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