

Effective Measures Coping with COVID-19 Pandemic Based on fsQCA: Evidence from China

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Research Article

Keywords: COVID-19, emergency measures, effectiveness assessment, fsQCA, emergent infectious diseases

Posted Date: August 6th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-51776/v1>

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Effective measures coping with COVID-19 pandemic based on fsQCA: Evidence from China

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Abstract

Background: Faced with the global outbreak and spread of COVID-19 pandemic, the government of each country has adopted different emergency measures, but the effectiveness assessment of these emergency measures is still lacked. This paper aimed to study the effectiveness of emergency measures for emergent infectious diseases to look for key measures and effective combinations.

Methods: We took COVID 19 pandemic management and control measures in China as an example, and selected five high frequency emergency measures including controlling population mobility, patient admission, appropriation of pandemic prevention funds, legal regulations and resumption of production from the perspective of Epidemiology. Using fuzzy set qualitative comparative analysis (fsQCA), we conducted necessary condition analysis and configuration analysis on these measures using official statistical data. And robustness test was performed by changing consistency threshold.

Results: We found that: (1) The consistency of the five emergency measures was less than 0.9, indicating that none of these measures can be used separately as a necessary condition for the strong pandemic prevention and control effects. (2) There were three combinations of emergency measures to achieve strong pandemic prevention and control effects, with solution consistency of 0.92 and solution coverage of 0.6: when all patients are admitted to hospitals, the

government provides sufficient pandemic prevention funds, and severely crack down on criminal cases; when resume production under the measures of strictly controlling population mobility and severely cracking down on criminal cases; when strictly control population mobility and all patients are admitted to hospitals without resumption production.

Conclusions: These findings suggest that fsQCA model can be applied to comprehensive effectiveness assessment of infectious diseases emergency measures. The results of our study not only help various countries prevent and control COVID-19 pandemic and its resurgence, but also have important reference significance for the emergency management of other emergent infectious diseases in the world.

Keywords: COVID-19; emergency measures; effectiveness assessment; fsQCA; emergent infectious diseases

1. Background

In the process of human development, infectious diseases have always been one of human disasters, especially the spread of emergent infectious diseases. The outbreak and spread of COVID-19 has spread to more than 200 countries and regions around the world, with a total of more than 8 million diagnosed cases and nearly 300,000 deaths, which makes it the most serious global crisis since World War II [1]. Scholars have done a lot of research on the spread mechanism and control measures of emergent infectious diseases. The researches related to this article can be summarized into two aspects.

Firstly, extensive work has been done in the area of infectious disease emergency management system and prevention and control measures. Some researchers have discussed

China's emergency management system and prevention and control measures. For example, Wangs et al. [2] found that a sound system of emergency reserve supplies is crucial to the management of public health emergencies by reflecting on the outbreak of SARS and COVID-19 of China, and improving the system of emergency reserve medical supplies should be emphasized in the process of establishing and improving public health emergency response systems. Xu et al. [3] and Zhao et al. [4] analyzed the prevention and control measures taken during the COVID-19 pandemic in Shenzhen and Zhengzhou provinces of China, such as input population control, urban internal population flow control, traffic control, etc., and evaluated the strength and effectiveness of these measures. Others have analyzed the health emergency management system and prevention and control measures of other countries, summed up their successful experience and pointed out the defects. For example, Li [5] comparatively analyzed the overall emergency management system and health emergency management system of typical countries such as the United States and Japan, and make recommendations for China's health emergency management system; Kamenidou et al. [6] took Greek citizens as the research object and found that the most common methods for citizens to prevent COVID-19 are avoiding non-mandatory transportation, contacting with individuals with respiratory symptoms, and individuals of high risk for severe illness; Reis et al. [7] used Brazil, Italy, and South Korea as the typical countries in the initial, peak, and controlled phases of COVID-19, respectively, and analyzed the importance of mitigation policies such as social distancing and isolation policies for controlling the spread of COVID-19. Other countries such as France and Germany have also adopted strict isolation and containment measures such as the “foot ban” and “social ban”, and achieved prevention and control results such as a decline in hospital admissions and a

66 slowdown in the pandemic. But due to the late start of these policies, the number of infected
67 people in both countries is greater, and the situation of pandemic prevention and control is more
68 severe. Besides, the attitude adopted for the prevention and control of COVID-19 pandemic in
69 the United Kingdom and the United States was mainly the natural law of group immunity and
70 survival of the fittest, resulting in a wide range of infections and deaths.

71 The other aspect of researches related to this article is the study of methods and models of
72 emergency management for infectious diseases. The predictive model of infectious diseases can
73 provide data support for emergency management policies and reduce socioeconomic harm. The
74 emergency management simulation model can simulate different scenarios and be applied to
75 policy analysis and evaluation. Geng et al. [8] built a SEIR model and added new parameters of
76 latent infection rate and change rate of infected, found that the isolation measures based on
77 strict travel restrictions could slow down the development trend of COVID-19 incidence curve,
78 Similarly, Chinazzi et al. [9] using a global metapopulation disease transmission model,
79 revealed that the travel quarantine of Wuhan delayed the overall COVID-19 epidemic
80 progression in Mainland China and had a more marked effect at the international scale.
81 Additionally, Zhou et al.[10] develop a seeding time and doubling time model to assess risk and
82 response during COVID-19 epidemics, which can help decision makers take decisive action
83 timely.

84 Compared with other countries in the world, China's early prevention and control of
85 COVID-19 pandemic has been effective. Lai et al. [11] believe that China's combined
86 non-pharmaceutical interventions, including inter-city travel restrictions, early identification
87 and isolation of cases, as well as contact restrictions and social distancing measures, have

88 greatly curbed the spread of COVID-19 pandemic in China. However, there are two
89 shortcomings in the existing researches on the emergency management of public health
90 emergencies including emergent infectious diseases. From the perspective of visual angle, most
91 researches focus on the construction and specification of concepts, systems, mechanisms at the
92 macro level, and there are little researches on the effects of specific comprehensive factors
93 management and control measures for emergent infectious diseases. From the perspective of
94 research methods, there are many studies on putting prevention and control measures into the
95 model for analysis, and few studies on the comprehensive evaluation on the effects of
96 management and control measures.

97 Currently, one of the most popular and effective method for the effectiveness assessment
98 of various management measures is QCA (Qualitative Comparative Analysis). QCA is an
99 emerging research method in the field of social sciences, which was first proposed by
100 sociologist Charles Ragin in the 1980 [12]. Complex causality contained in social phenomena is
101 explored based on Boolean algebra and set theory by case-oriented analysis. With the
102 continuous development of QCA, three analysis techniques include crisp-set QCA (csQCA),
103 fuzzy-set QCA (fsQCA), and multi-value QCA (mvQCA) have gradually formed [12]. Due to
104 QCA has obvious advantages in solving the logical relationship between multiple causal
105 conditions and a specific result, more and more scholars have begun to pay attention to this
106 method. Its applications have penetrated into a host of fields, including innovation management,
107 international business, human resource management, stakeholder management, organizational
108 design, strategic management, knowledge management, entrepreneurial management, and
109 consumer behavior [13].

Consequently, we focus on the management and control measures of the COVID-19 pandemic in China. Using official statistical data, we access the effects of emergency measures for emergent infectious diseases to look for key measures and their effective combinations using fuzzy-set qualitative comparative analysis (fsQCA). Accordingly, from the perspective of Epidemiology, five high-frequency emergency measures such as controlling population mobility, patient admission, appropriation of epidemic prevention funds, legal regulations and resumption of production are selected. In the fsQCA model, the five pandemic emergency measures and emergency management effect were used as condition variables and outcome variables, respectively. Sample data from 31 provinces (autonomous regions and municipalities) in China are input to train an fsQCA optimization model. Through the necessary condition analysis and condition configuration analysis of the model, we find out key measures and their combinations that resulting strong pandemic prevention and control effects and put forward several corresponding policy recommendations. The results of our study not only help various countries prevent and control COVID-19 pandemic and its resurgence, but also have important reference significance for the emergency management of other emergent infectious diseases in the world.

2. Methods

2.1 FsQCA

FsQCA has quantitative expressions in qualitative analysis, it is good at dealing with the multiple conjunctural outcome evaluation and the cause analysis for the strength or weakness of management effects. Therefore, we use fsQCA to study the effect of COVID-19 pandemic

emergency measures. The basic thought of fsQCA is to use set theory and Boolean operations as the cornerstones of its methodology, to explore the general characteristics of multiple cases by discussing the membership relationship between sets, and to analyze the set relationship between condition sets and outcome sets of cases [14, 16].

The application steps of fsQCA are: (1) Identify the research object, meanwhile determine the outcome variables and screen the appropriate cases. (2) Determine the condition variables, collect and calibrate the data in the unit of a single case sample, analyze the necessary conditions of the single factor, and construct the truth table. (3) Solve the truth table in fsQCA software, check the necessity of a single factor, and then conduct the configurations analysis. Use consistency to determine whether the logical condition combinations constitute sufficient or necessary conditions for the outcome variable. Use coverage to analyze the ability of logical condition combination to explain the outcome variable [15]. Consistency refers to the degree of consistency of cases with common conditional configuration that belong to a same outcome, and coverage refers to the extent of the set relationships that passes the consistency test interpret the outcome [12].

The model solution software is fs/QCA 3.0 [16].

2.2 Data and preprocess

2.2.1 Variable design and case selection

The key step in performing fsQCA analysis is the selection of variables. We select the newly confirmed cases from the pandemic notification data released by National Health Commission of the People's Republic of China as the measurement indicators of the pandemic

prevention and control effect [17]. The selection perspectives of the condition variable are controlling the source of infection, cutting off the route of transmission, protecting susceptible people and resumption of production. The selected time period is the outbreak period of COVID-19 pandemic, which is between January 26 and February 19, 2020.

(1) Controlling the source of infection

In terms of controlling the source of infection, the taken measures are firstly controlling population mobility and secondly patient admission. Population mobility increases the risk of infection, so the sum of newly diagnosed and suspected populations is used as a measure to control population mobility. The measurement index of the patient admission is the number of local designated hospitals and hot clinics for patients with COVID-19.

(2) Cutting off the route of transmission

The transmission routes of COVID-19 are contact transmission and droplet transmission, which mainly depend on person-to-person transmission. Therefore, measures to cut off the transmission route are mainly to prevent crowds from gathering. In the case of controlling population movement, the problem of crowding is prevented naturally.

(3) Protecting susceptible people

The most effective protection measure for susceptible people is vaccination, but for emergent infectious diseases, there is no effective vaccine in the world and it cannot be developed in a short time. Therefore, the protection measures selected for the susceptible people in this paper include two aspects. Firstly, appropriate pandemic prevention funds to conduct epidemic prevention education, health education, disinfection in public places, and improvement of sanitary conditions. Secondly, carry out legal regulations to reduce the

manufacture and sale of fake medical supplies and crack down behaviors that impede the order of pandemic prevention and control. The measurement of appropriation of pandemic prevention funds uses the number of COVID-19 pandemic prevention funds in various regions. The legal regulation measures are the number of crimes related to the pandemic that have been cracked down during the pandemic.

(4) Resumption of production

Resuming production can maintain the normal operation of the national economy and increase the production of medical protection products that are in short supply. However, if the prevention and control measures are improper, the control of the pandemic may be broke down, so the resumption measures are also very crucial for pandemic control. The measurement index for resumption of production is the change in the number of newly diagnosed people after resumption of work in various regions.

In summary, the condition variables selected in this paper are subdivided into controlling population mobility, patient admission, appropriation of pandemic prevention funds, legal regulations and resumption of production. 31 provinces (autonomous regions and municipalities) in China are used as sample cases to collect and process data.

2.2.2 Data preprocess

Data preprocessing in this paper includes two aspects.

(1) Dimensionless

Due to the different population distribution and the risk of pandemic, the level of each indicator varies greatly. Therefore, in order to ensure the comparability and reliability of the

195 data, we carried out the dimensionless processing of the original data by the extreme value
 196 method. Here is the formula:

$$x_i' = \frac{x_i - |\min|}{|\max| - |\min|} = \frac{x_i - |\min|}{R} \in [-1,1] \quad (1)$$

197 (2)Calibration

198 Cases need to be calibrated before qualitative comparative analysis to make the cases
 199 interpretable. According to the fuzzy-set (fsQCA) analysis technology, we use the direct
 200 calibration method to calibrate the variable data. This method uses three important qualitative
 201 thresholds for structured calibration: full membership, full non-membership and the crossover
 202 point [18]. We set three qualitative thresholds for the target set based on the lower quartile,
 203 upper quartile, and median of the sample data [19]. The measurement index description of each
 204 variable and the determination of thresholds are shown in Table 1.

205 Table 1 Index description and calibration of outcome variable and condition variables

Variable	Index description	Fully In	Crossover	Fully Out
prevention and control effect	Number of newly diagnosed	0.024	0.011	0.004
controlling population mobility	sum of newly diagnosed and suspected populations	0.112	0.045	0.000
patient admission	number of designated hospitals and hot clinics for patients with COVID-19	0.103	0.062	0.024
appropriation of pandemic prevention funds	number of COVID-19 pandemic prevention funds	0.289	0.157	0.068
legal regulations	number of crimes related to the pandemic that have been cracked down during the pandemic	0.112	0.024	0.012
resumption of production	change in the number of newly diagnosed people after resumption of work	0.008	0.003	0.000

3. Results

3.1 Necessary condition analysis

Necessary condition analysis is carried out first before configuration analysis to detect whether a single variable is a necessary condition for the outcome variable, using consistency and coverage to determine. Consistency refers to the degree of consistency of cases with common conditional configuration that belong to a same outcome, and coverage refers to the extent of the set relationships that passes the consistency test interpret the outcome [12]. Their calculation formulas are as follows, Where X represents the set of condition variables and Y represents the set of outcome variables. It is generally believed that the consistency detection standard is reached when the consistency score is greater than 0.9, that is, the variable constitutes a necessary condition for the outcome [20].

$$\text{consistency}(X_i \leq Y_i) = \sum [\min(X_i, Y_i)] / \sum (X_i) \quad (2)$$

$$\text{coverage}(X_i \leq Y_i) = \sum [\min(X_i, Y_i)] / \sum (Y_i) \quad (3)$$

Perform necessary condition analysis on the calibrated data, the results are shown in Table 2.

Table 2 Necessary condition analysis for the strong prevention and control effect of

COVID-19

Condition Variable	consistency	coverage
controlling population mobility	0.525182	0.530743
~controlling population mobility	0.584845	0.561953
patient admission	0.714454	0.746732
~patient admission	0.373305	0.347752
appropriation of pandemic prevention funds	0.689567	0.651991
~appropriation of pandemic prevention funds	0.392298	0.40334
legal regulations	0.705875	0.752181
~legal regulations	0.417251	0.382161
resumption of production	0.700701	0.669231

~resumption of production	0.390988	0.397655
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Notes: Wavy lines “~” indicate “NO/Not”.

According to the results of necessary condition analysis for the strong prevention and control effect of COVID-19 in Table 2, the consistency of each condition is lower than the critical value of 0.9, which shows that none of these five conditions can constitute the necessary conditions for explaining the outcome variable, that is, none of the five prevention and control measures can be used as a necessary condition for strong pandemic prevention and control effects, or the ability to independently explain strong pandemic prevention and control effects is weak. This result shows the complexity of pandemic prevention and control, that is, controlling population mobility, patient admission, appropriation of pandemic prevention funds, legal regulations and resumption of production need to be coordinated with each other to effectively prevent and control COVID-19 pandemic. Accordingly, it is necessary to perform configuration analysis on these condition variables and consider the conjunctural synergistic effect of multiple conditions.

3.2 Configuration analysis

Three kinds of solutions can be obtained from conditional configuration analysis of variables: complex solution, intermediate solution and parsimonious solution. Generally, scholars tend to analyze intermediate solutions because they are close to theoretical reality and not too complicated [21]. Consequently, we will focus on the analysis of the intermediate solution.

We divide the causal conditions into core conditions and peripheral conditions, and organizes them according to the international form of QCA research results [22], see Table 3.

241 The core condition refers to a condition that has an essential meaning to the interpretation of the
 242 outcome variable, and appears in both the parsimonious solution and the intermediate solution;
 243 the peripheral condition refers to a condition that has no essential influence on the interpretation
 244 of the outcome variable and can be replaced, only appears in the intermediate solution. In table3,
 245 black circles (“●”) indicate the presence of a condition, and circles with a cross-out (“⊗”)
 246 indicate its absence. Furthermore, large circles indicate core conditions, and small circles refer
 247 to peripheral conditions. Short horizontal line(“–”)in a solution indicate a “don’t care” situation
 248 in which the causal condition may be either present or absent.

249 Table 3 Configurations of achieving strong pandemic prevention and control effects

causal condition	Configuration			
	1	2	3	4
controlling population mobility	⊗	●	●	●
patient admission	●	⊗	●	–
appropriation of pandemic prevention funds	●	–	⊗	●
legal regulations	●	●	⊗	●
resumption of production	–	●	⊗	●
consistency	0.921225	0.903602	0.868545	0.933902
raw coverage	0.275722	0.116642	0.12116	0.286856
unique coverage	0.20892	0.0079245	0.0864497	0.153252
solution consistency	0.917091			
solution coverage	0.601284			

250 Notes:Black circles indicate the presence of a condition, and circles with “×” indicate its absence.
 251 Large circles indicate core conditions; small ones, peripheral conditions. Short horizontal lines indicate
 252 “don’t care.”

253 Four paths that can explain the effects of strong pandemic prevention and control are
 254 presented in Table 3. The solution consistency is 0.92, which means that in all the pandemic
 255 prevention and control cases that meet these four configurations, 92% of those are at a high
 256 level of epidemic prevention and control effects. The solution coverage is 0.6, which means that

the four configurations can explain 60% of the cases of strong pandemic prevention and control effects. The solution consistency and solution coverage both are higher than the critical value, indicating that the empirical analysis is effective.

3.3 Robustness test

Robustness testing is a crucial analysis step in QCA research [20]. Commonly used robustness testing methods include set theory specific methods and statistical theory specific methods. Zhang and Du [23] believe that QCA research results based on set theory should give priority to set theory specific method to test robustness. Therefore, we choose the method of changing consistency threshold, which is one of the specific robustness test methods of set theory, for the robustness test. We adjusted consistency threshold from 0.8 to 0.85, and conducted configuration analysis again, and the final result was exactly the same as the configuration analysis result when the consistency threshold was 0.8, proving that the fsQCA results are robust.

4. Discussion

We group configurations which has same core conditions to be the following three situations.

Situation 1, namely configuration 1, the core conditions are patient admission, appropriation of pandemic prevention funds and legal regulations. This situation indicates that a high-intensity pandemic prevention and control effect will be achieved when all patients are admitted to hospitals, the government provides sufficient pandemic prevention funds, and

277 severely crack down on criminal cases that violate laws and regulations. The corresponding
278 cases are shown of square in Figure 1. The cases that configuration 1 can explain include three
279 provinces of Zhejiang, Guangdong and Jiangsu. As one of the typical cases, Jiangsu Province
280 has opened 770 designated hospitals and hot clinics for COVID-19 medical treatment, ensuring
281 that diagnosed and suspected patients can be detected and treated effectively in time. Since the
282 pandemic occurred, the financial departments in Jiangsu Province raised funds quickly to
283 ensure the need for pandemic prevention and control can be satisfied. As of March 2, 2020,
284 financial departments at all levels have allocated 5.466 billion yuan, which is mainly used for
285 medical treatment of diagnosed and suspected patients, procurement of equipment and materials,
286 medical personnel subsidy, renovation of isolation wards, medical waste disposal, public area
287 disinfection, and research and development of testing reagents and vaccines, etc. Since late
288 January 2020, the public security office of Jiangsu Province have investigated and dealt with
289 3399 criminal cases and 11248 administrative cases involving COVID-19 pandemic. Eight
290 major criminal cases in the province have decreased by 38% year-on-year, and no influential
291 major vicious cases have occurred, which has made outstanding contributions to maintaining
292 the order of pandemic prevention and control. Under the three-pronged approach, the number of
293 COVID-19 newly diagnosed cases in Jiangsu Province from 23 daily on January 27 to 0 on
294 February 19, strongly illustrating the obvious prevention and control effect brought by these
295 measures.

296 Situation 2, including configuration 2 and configuration 4, the core conditions are
297 controlling population mobility, legal regulation and resumption of production. This shows that
298 under the measures of strictly controlling population mobility and severely cracking down on

299 criminal cases that violate laws and regulations, resumption of production can still achieve a
300 high-intensity pandemic prevention and control effect, and it has not brought a negative impact
301 on pandemic prevention and control. Measures to control population movements include
302 mandatory isolation of diagnosed and suspected patients, strict prohibition of residents dropping
303 around, dinners, gatherings, and strict 14-day home isolation for returnees. Taghrir et al. [24]
304 also proved the key role of large-scale isolation in the prevention and control of COVID-19
305 pandemic. Compared with configuration 2, configuration 4 also emphasizes the peripheral
306 significance of the measure for appropriation of pandemic prevention funds. The corresponding
307 case of configuration 2 is Anhui (as shown of circle in Figure 1), and the corresponding cases of
308 configuration 4 include Anhui, Henan, Shandong and Sichuan (as shown of triangle in Figure 1).
309 Taking Henan as a typical case, the number of newly diagnosed and suspected in Henan has
310 decreased by 15 and 906 respectively in the next three days after government of Henan
311 Province issued the requirement of “strictly implement isolation measures and immediately stop
312 public gathering activities with obvious cross infections” on February 12. Henan Province also
313 strongly cracks down on pandemic-related crimes, focusing on crimes that disturb medical
314 order, violently hurt medical staff, and interfere in pandemic prevention work, as well as
315 manufacture and sale of counterfeit and shoddy medical items, and fraud of pandemic-related
316 supplies, and crimes that raise prices, hoard medical items, and make rumors. As of March 12,
317 Henan public security office punished a total of 6,757 criminal cases involving COVID-19
318 pandemic. Regarding resumption of production, enterprises in Henan Province have started to
319 resume work successively since February 10, with the prevention and control of the pandemic
320 on the one hand and the resumption of production on the other hand supported by a number of

321 measures. Instead of causing a rebound in the pandemic, the number of pandemic cases
322 continued to decline, which can be confirmed by the number of confirmed cases fell by 17 three
323 days after resuming production. In addition, Henan Province's finances have cumulatively
324 allocated 3.841 billion yuan for pandemic prevention and control till February 13, which
325 effectively ensures the demand for pandemic prevention and control.

326 Situation 3, namely configuration 3, the core conditions are controlling population
327 mobility, patient admission and non-resumption of production. This shows that in the case of
328 strict control of population mobility, all patients are admitted to hospitals and no resumption
329 production, a high-intensity pandemic prevention and control effect can be achieved. However,
330 in order to ensure economic operation and basic people's livelihood needs, all parts of the
331 country have begun to resume production, so configuration 3 has no specific corresponding
332 case to analyze. But it is generally acknowledged that under the measures of controlling the
333 source of infection (controlling population movement and patient admission) and avoiding the
334 second outbreak of pandemic (not resuming production), a high-intensity pandemic prevention
335 and control effect will inevitably be achieved.

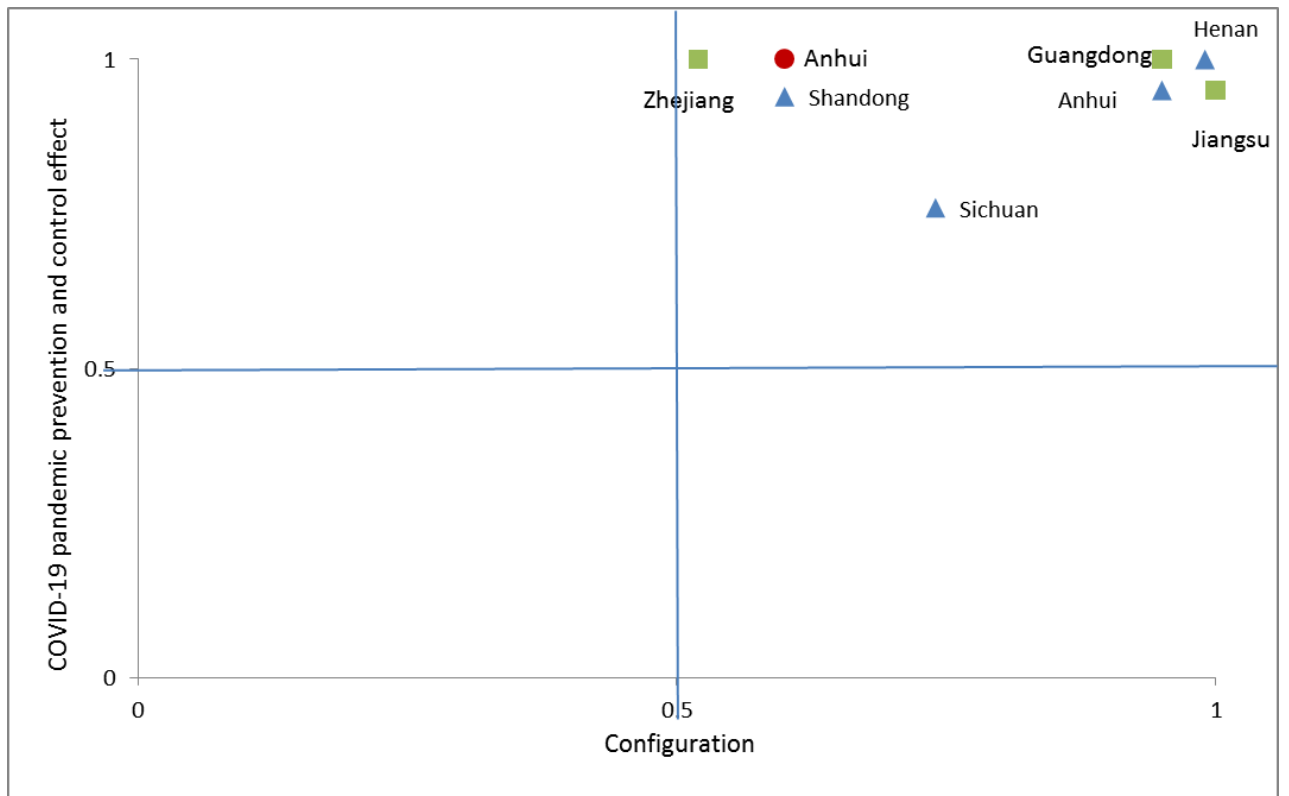


Figure 1 Corresponding cases of configurations

Notes: Squares indicate corresponding cases of configuration 1, circles indicate configuration 2, triangles indicate configuration 4.

Although we have studied the effects of emergency measures for emergent infectious diseases, there are still some limitations of our study. First, we don't cover all pandemic prevention and control measures such as external assistance, vaccination, etc. Future research can take other emergency measures in to consideration from different perspectives and discuss key measures and combinations. Second, the implementation of specific policies will be different more or less due to differences in systems and cultural customs among countries. Therefore, the institutional and cultural differences among countries should be taken into account in future research to extract commonalities and apply to the emergency management of global infectious diseases better.

5. Conclusions

We took COVID-19 pandemic in China as an example, from the perspective of Epidemiology, five high-frequency emergency measures including controlling population mobility, patient admission, appropriation of pandemic prevention funds, legal regulations and resumption of production are selected. Using fuzzy set qualitative comparative analysis (fsQCA), we studied the effects of emergency measures for emergent infectious diseases to look for key measures and their effective combinations. Four main conclusions we concluded are as follows.

(1) None of the five emergency measures can be used as a necessary condition for strong pandemic prevention and control effects, or the ability to independently explain strong pandemic prevention and control effects is weak. In other words, the emergency management of infectious diseases cannot be completed by a certain department or a certain measure, but it needs collaboration of various subjects including governments, professional institutions and social organizations in order to obtain efficacious prevention and control effect.

(2) The government should increase the input of pandemic prevention funds to ensure that pandemic prevention needs such as medical treatment, procurement of medical materials, and vaccine research and development are met. Timely expansion and reconstruction of treatment hospitals should be carried out to ensure that patients are tested and treated immediately. It also should severely crack down on illegal acts that disturb the medical order and interfere with pandemic prevention, such as manufacturing and selling counterfeit and shoddy medical supplies, raising prices, and spreading rumors.

(3) Under the measures of strictly controlling population mobility and severely cracking

371 down on criminal cases that violate laws and regulations, resumption of production can still
372 achieve a high-intensity pandemic prevention and control effect, and it will not bring a negative
373 impact on pandemic prevention and control. Measures to control population movement include
374 mandatory isolation of diagnosed, suspected patients and close contacts, banned gathering
375 activities such as dinners, parties, and exhibitions, and temporarily closing places other than the
376 public places necessary to guarantee the lives of the masses. You can also formulate relevant
377 laws or issue legally effective notices to ensure the smooth implementation of the above
378 measures. In addition, with proper protection measures, a reasonable and orderly resumption of
379 production will not have a negative impact on the prevention and control of infectious diseases,
380 instead it can increase the production to alleviate the shortage of medical supplies, protect the
381 residents normal life and maintain a stable social order.

382 (4) In the case of strict control of population mobility, all patients are admitted to hospitals
383 and no resumption production, a high-intensity pandemic prevention and control effect can be
384 achieved. However, due to the inability to resume production, the supply of medical items, the
385 guarantee of residents' normal life and the stability of social order will be affected.
386 Consequently, it is recommended to adopt a differentiated combination of prevention and
387 control measures unless the pandemic spreads rapidly or is already difficult to control.

388 These conclusions suggest that fsQCA model can be applied to comprehensive
389 effectiveness assessment of infectious diseases emergency measures. Moreover, efficacious
390 prevention and control effect of infectious diseases emergency management can be achieved
391 only when various subjects including governments, professional institutions and social
392 organizations and various measures carry out jointly. The results of our study not only help

393 various countries prevent and control COVID-19 pandemic and its resurgence, but also have
394 important reference significance for the emergency management of other emergent infectious
395 diseases in the world.

396 **6.Declarations**

397 **Ethics approval and consent to participate**

398 Not applicable.

399 **Consent for publication**

400 Not applicable.

401 **Availability of data and materials**

402 The datasets used and analysed during the current study are available from the
403 corresponding author on reasonable request.

404 **Competing interests**

405 The authors declare that they have no competing interests.

406 **Funding**

407 This work was supported by the Special fund of Ministry of education of the People's
408 Republic of China (grant number 2652 0200 01) and National Natural Science Foundation of
409 China (NSFC) (grant number 7167 3256). The study sponsor had no role in study design; in the

410 collection, analysis, and interpretation of data; in the writing of the report; and in the decision to
411 submit for publication.

412 **Authors' contributions**

413 H.L developed the original idea. All authors designed this study, collected and analyzed the
414 data. X.B established the model and wrote the first paper. All authors read and approved the
415 final manuscript. H.L. provided project funding support.

416

417 **Acknowledgements**

418 Not applicable.

419 **Authors' information**

420 The views and opinions expressed herein belong to the authors alone, and do not represent
421 the official policy, or endorsement of their affiliated institutions.

422

423 **Reference**

- 424 1. Boccaletti S, Ditto W, Mindlin G, Atangana A. Modeling and forecasting of epidemic
425 spreading: The case of Covid-19 and beyond. Chaos, Solitons and Fractals.
426 2020;135:109794.
- 427 2. Wang X, Zhang X, He J. Challenges to the system of reserve medical supplies for public
428 health emergencies: Reflections on the outbreak of the severe acute respiratory syndrome

coronavirus 2 (SARS-CoV-2) epidemic in China. Biosci Trends. 2020;14(1):3–8.

3. Xu R, Wang J, Ye S, Wang X. Analysis of prevention measures in Shenzhen based on SIQR model during the novel coronavirus pneumonia. Shenzhen Daxue Xuebao (Ligong Ban)/Journal Shenzhen Univ Sci Eng. 2020;37(3):257–64.
4. ZHAO H, Jiachen W, Shuang W, Yaxin L, Guanghui L, Changhong M. The Risk Assessment of Covid-2019 Epidemic in Metropolis and Precise Prevention and Control Measures: A Case Study of Zhengzhou City. Econ Geogr. 2020;40(4):103-9,124.
5. Li X. Study on the countermeasures to improve the national public health emergency management system. Adm Reform. 2020;(4):13–21.
6. Kamenidou IE, Stavrianea A, Liava C. Achieving a Covid-19 Free Country: Citizens Preventive Measures and Communication Pathways. Int J Environ Res Public Health. 2020;17(13):6–10.
7. Reis RF, de Melo Quintela B, de Oliveira Campos J, Gomes JM, Rocha BM, Lobosco M, et al. Characterization of the COVID-19 pandemic and the impact of uncertainties, mitigation strategies, and underreporting of cases in South Korea, Italy, and Brazil. Chaos, Solitons and Fractals . 2020;136:109888.
8. GENG H, XU A, WANG X, ZHANG Y, YIN X, MA M, et al. Analysis of the role of current prevention and control measures in the epidemic of Corona Virus Disease 2019 based on SEIR model. J Jinan Univ Nat Sci & Med Ed. 2020;41(2):175–80.
9. Chinazzi M, Davis JT, Ajelli M, Gioannini C, Litvinova M, Merler S, et al. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. Science (80-). 2020;368(6489):395–400.

- 451 10. Zhou L, Liu JM, Dong XP, McGoogan JM, Wu ZY. COVID-19 seeding time and doubling
452 time model: An early epidemic risk assessment tool. *Infect Dis Poverty*. 2020;9(1):1–9.
- 453 11. Lai S, Ruktanonchai NW, Zhou L, Prosper O, Luo W, Floyd JR, et al. Effect of
454 non-pharmaceutical interventions to contain COVID-19 in China. *Nature* . 2020; doi:
455 10.1038/s41586-020-2293-x.
- 456 12. Du Y, Jia L. Configuration perspective and qualitative comparative analysis (QCA): a new
457 path for management research. *Manage World*. 2017;(6):155–67.
- 458 13. Zhang C, Zheng X, Wang F. The Application of Qualitative Comparative Analysis (QCA)
459 in Configuration Research in Business Administration Field:Commentary and Future
460 Directions. *Foreign Econ Manag*. 2017;39(4):68–83.
- 461 14. XIA X, HE J, LIU J. Research Logic of Qualitative Comparative Analysis: On Its
462 Implications for Economic Management Research. *J Financ Econ*. 2014;40(10):97–107.
- 463 15. Rihoux B, Ragin CC. Configurational comparative methods:qualitative comparative
464 analysis (QCA) and related techniques. Thousand Oaks: Sage; 2009.
- 465 16. Ragin C, Sean D. Fuzzy-Set/Qualitative Comparative Analysis 3.0. Irvine, California:
466 Department of Sociology, University of California; 2016.
- 467 17. National Health Commission of the People’s Republic of China. <http://www.nhc.gov.cn/>
468 Accessed 21 May 2020.
- 469 18. Ragin C. Redesigning Social Inquiry: Fuzzy Sets and Beyond .University of Chicago Press;
470 2008.
- 471 19. Coduras A, Clemente JA, Ruiz J. A novel application of fuzzy-set qualitative comparative
472 analysis to GEM data. *J Bus Res*. 2016;69(4):1265–70.

- 473 20. Schneider CQ, Wagemann C. Set-theoretic methods for the social sciences: A guide to
474 qualitative comparative analysis. Cambridge University Press; 2012.
- 475 21. Crilly D, Zollo M, Hansen MT. Faking it or muddling through understanding decoupling
476 in response to stakeholder pressures. *Acad Manag J.* 2012;55(6):1429–48.
- 477 22. Fiss PC. Building better causal theories: A fuzzy set approach to typologies in organization
478 research. *Acad Manag J.* 2011;54(2):393–420.
- 479 23. Zhang M, Du Y. Qualitative Comparative Analysis(QCA)in Management and
480 Organization Research:Position,Tactics,and Directions. *Chinese J Manag.*
481 2019;16(9):1312–23.
- 482 24. Taghrir MH, Akbarialiabad H, Marzaleh MA. Efficacy of mass quarantine as leverage of
483 health system governance during COVID-19 outbreak: A mini policy review. *Arch Iran*
484 *Med.* 2020;23(4):265–7.

Figures

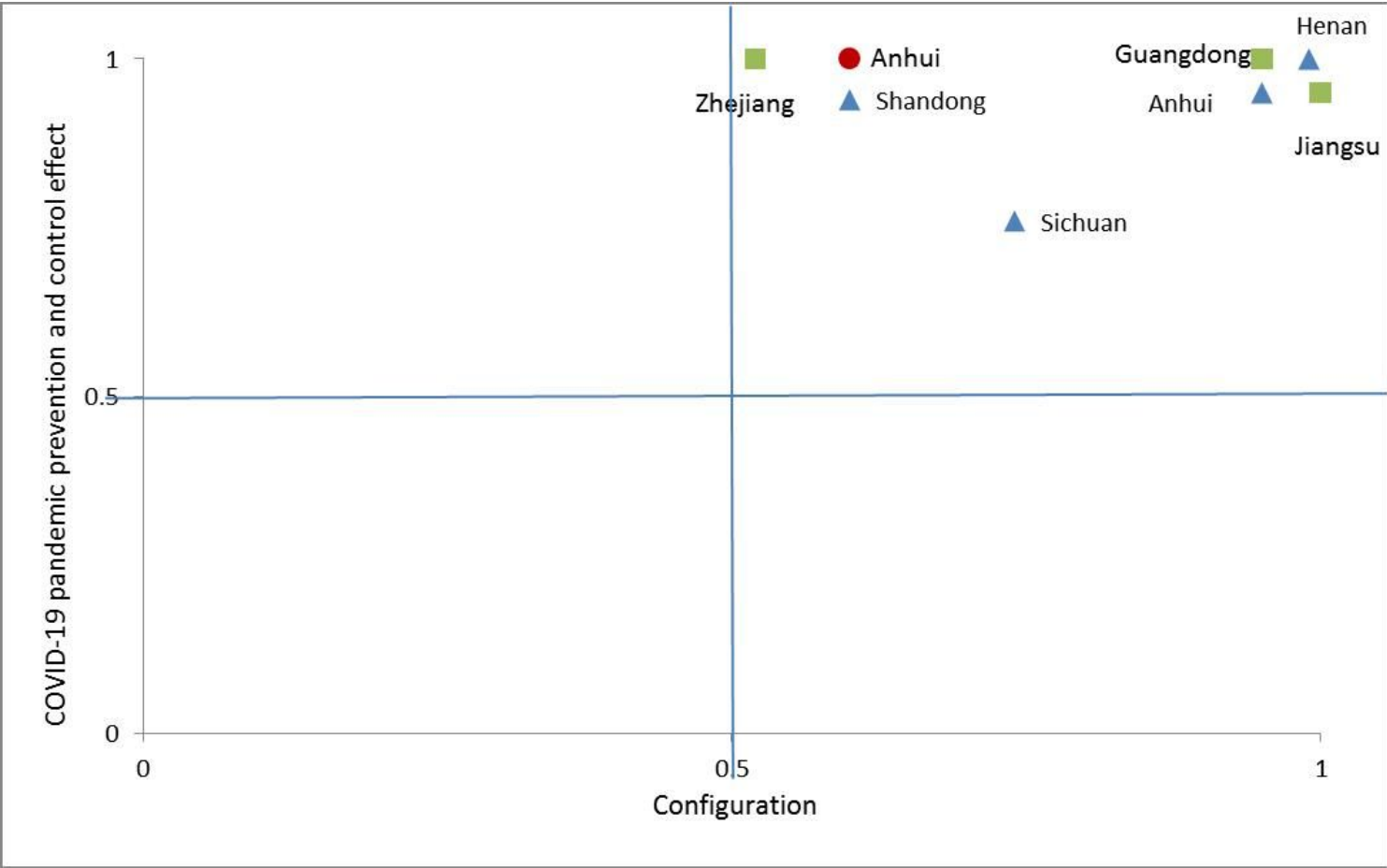


Figure 1

Corresponding cases of configurations