Quantitative Assessment for the Impact of Novel Coronavirus Pneumonia Epidemic on Economic Viability in A Domestic Area

Jun Zhang[1], *Xiangdong* Liu[2, *] and *Xiting* Jin[2]

[1] School of Economics and Management, South China Normal University, Guangzhou 511400, China
[2] School of Economics, Jinan University, Guangzhou 510632, China

Abstract. To combine the economic viability of urban areas with a quantitative condition that can characterize "epidemic" and "Pandemic" diseases, we use the factor analysis method to achieve index dimensionality reduction and subjective and objective integration method to achieve optimal weight distribution. We develop a judgment model by taking into account broad factors such as the epidemic situation, population, medical care, economy, and policy. On this basis, we chose 15 common infectious diseases as detection data and used the judgment model to obtain the specific quantitative judgment conditions of "spread, outbreak, epidemic, and pandemic." The threshold for defining epidemics is between 3 and 5, and the threshold for defining pandemics is greater than 5.

1 Problem background

The World Health Organization declared viral pneumonia (COVID-19) caused by the coronavirus sweeping the world a pandemic on March 12, 2020. The WHO last declared a pandemic during the H1N1 flu outbreak in 2009, but the decision was criticized at the time for instilling unnecessary fear. Despite affecting 26 countries, SARS and MERS are not considered pandemics. It is worthwhile to consider how to define the "pandemic." The World Health Organization defined the pandemic as "the global spread of new diseases." There are no rigorous quantitative criteria for reaching pandemic levels at the moment, nor are there thresholds for the number of cases or deaths that trigger this definition. At present, more than 200 countries/regions have reported virus infection cases. How more effective quantitative indexes can be given to the epidemic is of great concern to WHO and the world.

At the same time, the emergence of asymptomatic infection cases, which have tested positive for coronavirus in respiratory specimens, has raised concerns about whether they could become a new source of infection. It is difficult to identify asymptomatic infection cases and it has been a problem of great concern to countries all over the world about how to identify and judge them quickly, accurately, and with minimal cost.

* Corresponding author. Email: 1271525448@qq.com

Since the outbreak of the new coronavirus, great progress has been made in epidemic prevention and control under the leadership of the CPC Central Committee. Because China adheres to the goal of economic and social development this year, maintaining steady economic performance has a direct bearing on overall economic and social stability.

Our team began its analysis of the features of sudden, widespread epidemics and the means by which to damage the economy by starting with the national conditions and current affairs. This essay examines the economic damage brought on by the unexpected, widespread epidemic and its effects on the growth of the national economy at the micro, supply and demand, and macro levels, as well as the relationships between these levels. From different regions and different industries, we analyzed dynamic change trends of economic vitality. Furthermore, construct an appropriate economic model to analyze and calculate the economic losses caused by sudden large-scale epidemics, and put forward effective suggestions. It is of great significance for the formulation of Relevant countermeasures.

2 Modeling and solving

We employ the factor analysis approach to achieve index dimensionality reduction and the subjective and objective integration method to achieve optimal weight distribution in order to provide a quantitative condition that may define "epidemic" and "Pandemic" diseases. We create a judgment model by taking into account broad elements including the epidemic situation, population, medical treatment, economy, and policy. Based on this, we chose the pertinent information about 15 infectious diseases that are commonly found as the detection information, and we used the judgment model to obtain the precise quantitative judgment conditions for "spread, outbreak, epidemic, and pandemic."

2.1 Selection and Construction of Model indexes

2.1.1 Epidemic index

After data collection and literature review, we finally selected four indexes to measure the epidemic situation, namely: average spread rate, number of infections, number of cured people, and number of deaths.

We use time series data to select the period when the number of confirmed cases doubled for the first time-the period when the number of confirmed cases decreased continuously for one week, that is, the period of high transmission rate-as the base period for the average transmission rate. The steps are as follows:

$$\mathrm{ASR} = \frac{\sum_{i=1}^{n}(X_{i+1} - X_i)}{nX_i}$$

Among them, n is the duration of the high infection rate, i is the date sequence, and ASR is the average growth rate of transmission.

2.1.2 Population index

Considering the influence of population density on the probability of transmission and the rate of transmission, the influence of population number on the proportion of confirmed cases, and the descriptive nature of the infected areas, we finally chose two indexes to measure the population situation, respectively: population density, population total.

2.1.3 Medical index

After relevant data collection and literature review[1], we finally selected three indexes to measure the medical conditions in the infected areas, namely, the proportion of health expenditure (the proportion of GDP), the number of doctors per thousand people, and the number of beds per thousand people.

2.1.4 Economic index

Given the importance of the infected area's economic condition in determining resistance to the epidemic, we include GDP in the economic evaluation index.

2.1.5 Policy index

We are acutely aware of the significance of policy aspects in containing the epidemic in this latest coronavirus outbreak. The Chinese government has acknowledged the issue, taken proactive and effective measures, and provided significant policy, economic, material, and spiritual support to the people. The Chinese people, acting as a unit, followed the rules at the same time and ultimately triumphed in the battle against the epidemic.

For the policy indexes, we take the quantitative processing of quality data. We carefully consider and assess if the government policy is appropriate and whether the populace can implement it in light of the current global circumstances and the features of the epidemic area. At the same time, we collect official news and make numerical scores by referring to many expert comments. Finally, all the data are combined to classify the scores into different interval levels, and finally use the four levels of 0, 1, 2, and 3 as policy indexes in the model.

To sum up, the selection of judgment model indexes is shown in the Table 1.

2.2 Subjective-objective integration method: weight calculation

2.2.1 Subjective weight assignment method——AHP

The main concept behind the hierarchy process is to approach the complex issue under study as a vast system affected by numerous factors, then break down the interrelated and mutually restrained factors into several orderly levels according to their subordinate relations, and finally compare and judge the degree of importance of each two indices in light of specific objective facts. The weight of the relevance of various schemes is derived through the study of each level, which serves as the basis for the choice of the best scheme, using a mathematical approach to establish the value of the order of the relative importance of all parts in each level [2]. These are the general steps:

Step1: Build a hierarchical model

Step2: Construct the judgment matrix $A = (a_{ij})_{n\times n}$

Step3: Hierarchical single sorting and consistency test

Step4: Consistency test: $CI = \frac{\lambda_{max}-n}{n-1}$, when $\frac{CR}{RI} \leq 0.10$, it is considered that the consistency of the judgment matrix is acceptable, otherwise, the judgment matrix should be corrected.

2.2.2 Objective weight assignment method——entropy weight method

The entropy weight method's fundamental tenet [3] is to calculate the objective weight in accordance with the magnitude of index variability. In general, an index's information entropy determines how much variance in its value, how much information it gives, how much of a part it can play in the overall evaluation, and how much weight it has. On the other hand, the lower the index's degree of fluctuation, the less information it provides, the less of a part it plays in the evaluation, and the smaller the weight, the higher the index's information entropy. These are the general steps:

Step 1: Calculate the information entropy of each standardized indexs_j;

$$s_j = -\frac{\log n}{\sum_{i=1}^{n} k_{ij} \log k_{ij}}$$

Among them, $k_{ij} = X_{ij} / \sum_{i=1}^{n} X_{ij}$,n is the number of samples.

Step 2: According to the entropy value, the weight coefficient W_j of each index is determined according to the principle that the weight coefficient is small when s_j is large:

$$W_j = \frac{1 - s_j}{m - \sum_{j=1}^{m} s_j}$$

Among them, $j = 1,2 \cdots m$, Represents m evaluation indexes.

2.2.3 Combination weighting of subjective weight and objective weight

To account for the evaluation index's subjectivity and objectivity, we will combine the subjective and objective weights to calculate the optimal weight.

Aiming at the evaluation index in the multi-index decision matrix, the multi-objective optimization model is transformed into a single-objective optimization model by using the basic idea of matrix estimation theory and the equal weight linear weighting method [4]:

$$\begin{cases} \min H = \\ \sum_{j=1}^{m} \alpha \sum_{s=1}^{l} (w_j - w_{sj})^2 + \sum_{j=1}^{m} \beta \sum_{b=l+1}^{l} (w_j - w_{bj})^2 \\ s.t. \sum_{j=1}^{m} w_j = 1 \\ 0 \le w_j \le 1, 1 \le j \le m \end{cases}$$

w_{sj} is the subjective weight set, w_{bj} is the objective weight set, m is the number of samples, and the relative importance coefficient of subjective weight and objective weight is α and β.

2.3 The solution of the model

2.3.1 Factor analysis method

Now we use SPSS to make a factor analysis of each index.

2.3.1.1 KMO and Bartlett tests

To ensure that the factor analysis method can be applied to the data, KMO and Bartlett tests are conducted on the data, and the results are shown in Table 2.

Table 2 shows that KMO>0.8, indicating a strong correlation between variables that is suitable for factor analysis. At the same time, the p-value of the Bartlett's sphere test is equal to 0.000, less than 0.05, indicating that the original hypothesis is rejected at the 95% confidence level, implying that the data is suitable for factor analysis.

2.3.1.2 Scree test

The Scree test is a method of determining the number of factors based on the scree plot. Kaiser proposed that the number of factors could be determined by directly observing the change of eigenvalues. When an eigenvalue has a large drop compared with the value of the previous eigenvalue, and this eigenvalue is small, the subsequent eigenvalue does not change much, indicating that adding factors corresponding to the eigenvalue can only increase very little information, so the first few eigenvalues are the number of common factors that should be extracted.

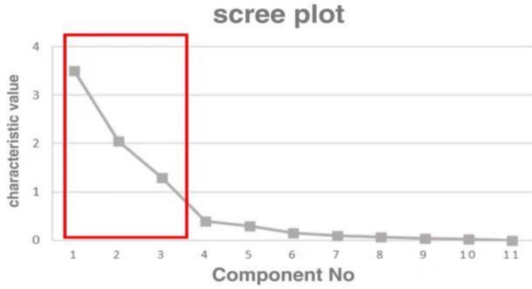

Fig. 1. Scree Plot

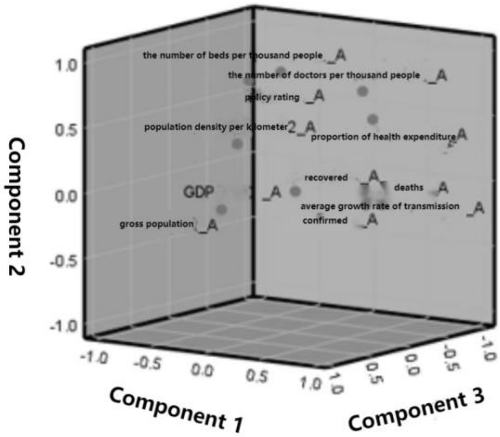

Fig. 2. Component diagram in rotated space

It can be seen from the scree plot that the change of the eigenvalues corresponding to the first three factors is steep. From the third factor, the change of the eigenvalues is relatively flat, so we should choose three factors for analysis.

2.3.1.3 Post-rotational component matrix

The factor load is the correlation coefficient between the variable and the common factor. When the absolute value of a load of a variable in a common factor is larger, it indicates that the variable is closer to the common factor, that is, the common factor is more representative of the variable.

Based on the Table 3, we define and explain three factors:

Factor 1: There are approximately equal and large positive loads in the number of infections, the number of cured people, the number of deaths, and the average growth rate of transmission, reflecting various aspects of epidemic information. We define it as an epidemic factor.

Factor 2: There is a large positive load on the number of doctors per thousand, the number of beds per thousand, the policy rating, and the proportion of health expenditure. The remaining variables are negative loads or small positive loads, which reflect policy factors and medical conditions. We define it as the anti-epidemic capability factor.

Factor 3: There is a large positive load on the total population, population density, and GDP, which reflects the population conditions and economic capacity. We define it as the regional basic characteristic factor.

2.3.2 Subjective-objective integration method

According to the model formula, the importance coefficient based on the above subjective and objective weights can be calculated: $\alpha = 0.5815, \beta = 0.4185$. On this basis, the optimal combination of evaluation index weights can be obtained by solving the nonlinear programming. The results are shown in Table 4.

2.3.3 Establish a decision model

Based on the results of factor analysis and the weight calculation of subjective and objective integration methods, we get the quantitative model:

$$Q = W_j \sum_{i=1}^{n} a_{ji}\, x_i$$

W_j is the weight determination, a_{ji} is the component score coefficient, x_i is the index data.

2.4 The formulation of quantitative definition conditions

In the field of epidemiology, the intensity of disease transmission can be divided into four levels: sporadic, outbreak, epidemic, and pandemic. [5] We selected 15 common infectious diseases from four types, cOVID-19, H1N1, SARS, MERS, H3N2, H2N2, plague, Hepatitis B, cholera, smallpox, measles, rubella, chicken pox, mumps, and polio. Substituting the epidemic data into the judgment model and drawing the Q value scatter diagram to effectively obtain the quantitative definition conditions.

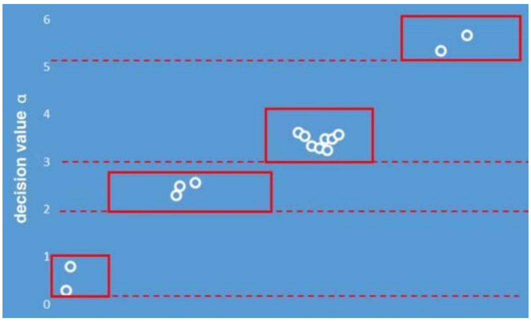

Fig. 3. Scatter plot

It can be seen from the scatter plot that the predicted results are comparatively ideal, and the four types of diseases are roughly in four intervals. Based on this, we can easily obtain the quantitative conditions for determining the type

On this basis, combined with the prevalence of regional infection, we predict the urban economic vitality.

3 The innovation of project

(1) PCA method can make the data set easier to use, reduce the computational overhead of the algorithm, and compared with LDA algorithm, LDA at most reduced to the category number K-1 dimension, PCA dimension reduction has no parameter limit. The establishment of grey prediction model with grey theory requires less data and accurate prediction, which improves our evaluation accuracy. The Hermite interpolation method has the advantages of continuity and smoothness, overcomes the large deviation between the high-order Lagrange polynomial and the original function, and improves the interpolation accuracy. Our team do the same kind of method optimization selection.

(2) Combining the economic theory model and the project evaluation model skillfully, this paper analyzes the economic loss caused by the outbreak of large-scale epidemic and its impact on the development of national economy from the micro, supply and demand, and macro levels, and the relationships between the various levels. This paper analyzes the dynamic changing trend of economic vitality from different regional and industrial sectors with different characteristics.

(3) Keep abreast of national priorities and hot spots of the times, and track data optimization model in real time. Starting from the national conditions and current affairs, based on data and case analysis, our team multiple data simulation to ensure that the rationalization of indexes, policy recommendations made reasonable.

4 Model improvement and promotion

The method of urban economic vitality and popularity evaluation system in this model can be extended to other demand evaluation systems. In the evaluation, statistical indexes are first selected according to the requirements and index selection principles, and then the indexes are weighted by factor analysis method, so as to form a multi-angle composite index.

References

1. He Ping. Some methods for eliminating outliers in measured data [J]. Aerial Survey Technology, 1995 (01): 19-22.
2. Shen Yuqi, Sheng Hongqi, Ma Guifeng, et al. Health input and health output of OECD countries: econometric analysis based on dynamic panel system GMM model [J]. China Health economy, 2019. 38 (7): 64-66. DOI: 10.7664/CHE20190716.
3. Guo Jinyu, Zhang Zhongbin, Sun Qingyun. Research and application of analytic hierarchy process [J]. Chinese Journal of Safety Science, 2008, 18 (5): 148.
4. Nie Hongzhan, Fang Lv Pan, Qiao Yi et al. Fuzzy comprehensive evaluation of transmission network planning scheme based on entropy weight method [J]. Grid Technology, 2009, 33 (11): 60-64.
5. Jiang Wenqi. Combinatorial weighting optimization method for multi-attribute decision making [J]. Operations and Management, 2006 15 (6): 40-43.
6. Shen Hongbing, Qi Xiuying. Epidemiology (8th Edition) [M]. Beijing: people's Health Publishing House, 201315.
7. MehataSuresh,Paudel Yuba Raj,DhungelAmit,PaudelMohan,ThapaJanak,Karki Deepak Kumar. Spousal Separation and Use of and Unmet Need for Contraception in Nepal: Results Based on a 2016 Survey.[J]. TheScientificWorldJournal, 2020, 2020.

Appendix

Table 1. The selection of judgment model indexes

Epidemic index	number of the infected	Number of the cured		death toll	average growth rate of transmission
Population index	gross population	population density			
Medical index	the number of doctors per thousand people	the number of beds per thousand people	proportion of health expenditure		
Economic index	GDP				
Policy index	policy rating				

Table 2. KMO and Bartlett tests

KMO sampling suitability quantity		.836
Bartlett tests	Approximate chi-square	231.438
	degree of freedom	55
	significance	.000

Table 3. Indicators and factors

indicator x_i	factor1 a_{1i}	factor2 a_{2i}	factor3 a_{3i}
number of the infected	0.890	-0.009	0.265
number of the cured	0.862	0.090	0.216
death toll	0.898	0.027	0.154
average growth rate of transmission	0.841	-0.08	-0.155
gross population	0.007	-0.04	0.907
population density	-0.462	0.289	0.727
proportion of health expenditure the	0.570	0.776	-0.096
number of doctors per thousand people the	0.430	0.857	-0.349
number of beds per thousand people	-0.097	0.869	-0.023
GDP	0.588	0.137	0.764
Policy rating	-0.184	0.838	0.2

Table 4. The optimal combination of evaluation index weights

factor	Factor meaning	Subjective weighting method	objective weighting method	optimal weight W_j
factor1	epidemic factor.	0.57369	0.4767	0.502631
factor2	anti-epidemic capability factor	0.28981	0.24584	0.251872
factor3	regional basic characteristic factor	0.1365	0.0962	0.125267

Table 5. The quantitative conditions for determining the type

type	*Determination interval of Q*
sporadic	[0,2)
outbreak	[2,3)
epidemic	[3,5)
pandemic	[5, ∞)