Assessment and Information System Establishment of the COVID-19 Impacts and countermeasures: Gray Prediction Model Applied in Analysis and Prediction

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Abstract. The outbreak of COVID-19 has had a huge impact on China's economic and social development, among which the tertiary industry has been severely impacted. As the epidemic prevention and control in China has achieved initial success and entered the normal prevention and control stage, it is very necessary to analyze the damage situation of industries directly affected by the epidemic. According to the historical data of various industries in China in the past five years, a grey prediction model was established to predict the normal development law of some economic indicators without an epidemic situation. Compared with the actual values in the first two quarters of 2020, we can estimate the economic and social losses caused by the COVID-19 epidemic. The epidemic has had the most serious impact on the tertiary industry, with retail, tourism, and catering sectors being hit hard. With the effective control of the epidemic, China's overall economic performance in the second quarter rose steadily. Many enterprises in the comprehensive service sector have been upgraded and transformed during the epidemic. From the current perspective, the epidemic will not have a serious impact on economic development throughout the year.

Keywords: COVID-19 epidemic, tertiary industry, grey prediction model.

1. Introduction
Since the outbreak of COVID-19 in Wuhan, Hubei Province in late December 2019, all walks of life across the country have been affected by COVID-19, and China's economic and social development has also been greatly impacted by the epidemic. In the first quarter of 2020, China's GDP growth slowed to -6.8%, with the tertiary industry suffering the most. Today, the tertiary industry has become the leading industry of China's economy, and in 2019 the tertiary industry accounted for up to 53.9% of GDP [7]. Due to the need to prevent further spread of the epidemic, various isolation and closure measures should be taken to avoid mass gatherings, thus reducing the number of residents going out [8]. All kinds of business, trade, and investment activities are temporarily interrupted, resulting in a short period of sharp decline in social aggregate demand, namely, consumption demand, investment demand, import, and export demand [14]. The outbreak has been accompanied by an economic shutdown. The epidemic is accompanied by the shutdown of the entire economy, which is even worse when for China's overall economic growth is already in a downward cycle, internal and
external pressure is greater under the situation, is even worse. The comprehensive integrated service industry needs a long time to recover [13]. It is necessary to analyze the damage of the tertiary industry and the industries directly affected by the epidemic, and then to provide suggestions for the severely affected industries. In order to estimate and predict the output value of various industries in China without COVID-19 epidemic, a gray prediction model was used. The model can be used to build a mathematical model and make predictions with a little information establish mathematical models and make predictions with a small amount of information. For small sample forecasting, the grey forecasting model is a convenient and effective tool with high precision.

2. Damage to value-added production of the tertiary industry

The COVID-19 epidemic has had a huge impact on the country's economic development, with the year-on-year GDP growth rate dropping to -6.8% in the first quarter of 2020. In the first quarter of 2020, the GDP growth rate dropped to -6.8% compared with the same period last year. Different industries have been affected to varying degrees. According to the quarterly data of GDP and value added of the three major industries from 2016 to 2019, the grey forecasting model can be used to predict the forecast value of GDP in each quarter of 2020 and the forecast value of the added value of the three major industries if the epidemic does not occur.

The value-added data of primary industry, secondary industry and tertiary industry in each quarter from 2016 to 2019 are known, as shown in Table 1 below.

| Year | Primary Industry | Secondary Industry | Tertiary Industry | Primary Industry | Secondary Industry | Tertiary Industry |
|------|------------------|--------------------|-------------------|------------------|--------------------|-------------------|
| 2016 | 7584.5           | 62905.4            | 91270.6           | 12221           | 74825.9           | 92941.2           |
| 2017 | 7815.1           | 66747.5            | 98597             | 12683.9         | 79483.8           | 100426.7          |
| 2018 | 8065             | 70884.6            | 106240.4          | 13110.2         | 84211.3           | 108584            |
| 2019 | 8279.5           | 75216.3            | 113627.1          | 13540.1         | 88895.8           | 116149.5          |

Considering that different quarters are affected by cycle fluctuations and other factors, the grey forecast analysis is carried out based on the annual data of each quarter. Based on the known data, taking the primary industry as an example, the industrial added value in the first quarter from 2016 to 2019 is marked as a sequence \( x^{(0)} = (x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), x^{(0)}(4)) \), and calculate the stage ratio of the sequence \( \lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)} \), \( k = 2, 3, 4 \) To ensure that all stages fall within the range \( \left[ e^{-\frac{2}{3}}, e^{\frac{2}{3}} \right] \).

And then I'm going to sum over \( x^{(0)} \).

\[
x^{(1)}(1) = x^{(0)}(1), x^{(1)}(2) = x^{(0)}(1) + x^{(1)}(2), x^{(1)}(3) = x^{(0)}(1) + x^{(0)}(2) + x^{(0)}(3), x^{(1)}(4) = x^{(0)}(1) + x^{(0)}(2) + x^{(0)}(3) + x^{(0)}(4) \]

Then we get a new sequence \( x^{(1)} = (x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), x^{(1)}(4)) \), the following first order linear differential equation is established for \( x^{(1)} \):
\[
\frac{dx^{(1)}}{dt} + ax^{(1)} = b
\]

(1)

The differential equation was solved to obtain the prediction model:

\[
x^{(1)}(k+1) = \left[ x^{(1)}(0) - \frac{b}{a} \right] e^{-ak} + \frac{b}{a}
\]

(2)

Because the above prediction model is an accumulation quantity, it is cumulatively reduced:

\[
\hat{x}^{(0)}(k+1) = (e^{-ak} - 1) \left[ x^{(0)}(4) - \frac{b}{a} \right] e^{-ak}
\]

(3)

After the model is selected, the rationality of the model is verified by the posterior difference test. By calculating the residuals \( e(k) = x^{(0)}(k) - \hat{x}^{(0)}(k), k = 1,2,3,4 \), the residuals sequence can be constructed.

Calculate the variance of the original sequence \( x^{(0)} \) and the residual sequence respectively \( S_1^2, S_2^2 \):

\[
S_1^2 = \frac{1}{4} \sum_{k=1}^{4} \left[ x^{(0)}(k) - \bar{x} \right]^2
\]

(4)

\[
S_2^2 = \frac{1}{4} \sum_{k=1}^{4} \left[ e(k) - \bar{e} \right]^2
\]

(5)

\[
\bar{x} = \frac{1}{4} \sum_{k=1}^{4} x^{(0)}(k), \bar{e} = \frac{1}{4} \sum_{k=1}^{4} e(k)
\]

The posterior difference ratio is \( C = \frac{S_2}{S_1} \). The accuracy level can be determined by referring to Table 2 below.

**Table 2** Reference table for posterior difference test discrimination

| Model accuracy grade | Posterior difference ratio \( C \) |
|----------------------|-------------------------------|
| Level 1 (good)       | \( C \leq 0.35 \)            |
| Level 2 (qualified)  | \( 0.35 < C \leq 0.5 \)     |
| Level 3 (barely)     | \( 0.5 < C \leq 0.65 \)     |
| Level 4 (rejected)   | \( 0.65 < C \)              |

MATLAB calculation to solve the model. Take the added value of the first quarter of the primary industry as an example, and the original number is listed as \( (7584.5, 7815.1, 8065, 8279.5) \).

Through the stage ratio test, the grey prediction model can be used[1]. The posterior difference ratio is 0.043299, and the prediction accuracy is good. The next fitting value is predicted to be...
8527.8858 (billion yuan), that is, if COVID-19 is absent in 2020, the added value of the primary industry in the first quarter will be 8527.8858 (billion yuan).

Similarly, the gray prediction model can be used to predict the added value of the primary industry in the second quarter, the secondary industry in the first and second quarters, and the tertiary industry in the first and second quarters in 2020 without the impact of COVID-19. Compared with the actual value of added value of the three industries in the first and second quarter of 2020, the approximate impact of COVID-19 epidemic on the output value of the three industries can be obtained.

\[ Loss = Actual\_value - predictive\_value \]

The results are shown in Table 3.

**Table 3** Loss of industrial added value in the first and second Quarter of 2020 (unit: 100 million YUAN)

| Industry           | The first quarter of 2020 | The Second quarter 2020 |
|--------------------|---------------------------|-------------------------|
| The first industry | -513.4                    | 2.8                     |
| The second industry| -11861.1                  | -935.3                  |
| The third industry | -14314.2                  | -6592                   |
Fig. 2 Loss of industrial added value in the first two quarters of 2020

As can be seen from the above chart, the COVID-19 epidemic has caused huge losses to all industries, especially the tertiary industry. After the resumption of work and production policy was issued, the output value of the secondary industry recovered relatively quickly, and the recovery of the tertiary industry was relatively stable due to the epidemic situation.

3. Analysis of the secondary industries
Sudden major public health events usually have the most direct impact on environmentally sensitive and crowd-oriented industries. To prevent the spread of the epidemic, mandatory measures should be taken for isolation and closure. As a result, consumer services such as retail, tourism and catering were the first to suffer a huge impact [2]. Therefore, the damage situation of the three industries will be analyzed respectively.

3.1. Retail trade
Given the growth rate of retail sales per quarter in 2019, see table 4 below. The growth rate of retail sales in the first quarter and the second quarter of 2020 can be predicted by the grey forecasting model.

| Industry          | The first quarter | The second quarter | The third quarter | The fourth quarter |
|-------------------|-------------------|--------------------|-------------------|--------------------|
| Supermarket       | 7.5               | 7.4                | 7                 | 6.5                |
| Department stores | 0.9               | 1.5                | 1.5               | 1.4                |
| Speciality store  | 3.9               | 5.3                | 3.8               | 3.2                |
| Exclusive agency  | -0.9              | 3                  | 1.4               | 1.5                |

Take the supermarket data as an example to establish the original sequence (7.5, 7.4, 7, 6.5). The grey prediction model can be used through the stage ratio test. The posterior difference ratio is 0.097814, indicating good prediction accuracy of the system. It can be predicted that the next fitting value is 6.1142 and the next fitting value is 5.7328. In other words, without the impact of COVID-19
epidemic, the retail sales growth rate of supermarkets in the first quarter of 2020 was approximately 6.1142, and the growth rate of retail sales in the second quarter was approximately 5.7328.

![Gray forecast fitting curve of supermarket retail sales growth rate](image)

**Fig. 3** Gray forecast fitting curve of supermarket retail sales growth rate

The data of department stores, specialty stores and exclusive agency all passed the grade test, and the gray prediction model could be used to make the prediction as above. The difference between the predicted and actual values of the four sets of data shows the approximate loss of the retail industry under the influence of COVID-19. The loss data is shown in Table 5.

|                      | The first quarter | The second quarter |
|----------------------|-------------------|--------------------|
| Supermarket          | -4.214            | -1.933             |
| Department stores    | -36.27            | -24.925            |
| Speciality store     | -27.051           | -15.905            |
| Exclusive agency     | -29.4592          | -14.8906           |
In addition to supermarkets, the added value of offline retail sales such as department stores, specialty stores and specialty stores all showed a precipitous decline. With the epidemic under more effective control in China, the recovery rate of retail sales is still relatively slow. This is partly due to the isolation measures taken by the epidemic, which has led to a sharp drop in human traffic; On the other hand, with the rise of e-commerce and the optimization of online shopping mode, the demand for offline consumption is also decreasing.

3.2. Tourism
The tourist data from 2010 to 2019 (as shown in Table 6 below) are available, which is conducive to the establishment of the original series of data. It has been verified to meet the stage ratio test. Therefore, the grey prediction algorithm can be used to predict the tourist person-times in 2020 without epidemic situation.

Table 6 Domestic tourist Arrivals over the years (million)

| Year   | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020(forecast) |
|--------|------|------|------|------|------|------|------|------|------|------|---------------|
| Tourist trips | 2103 | 2641 | 2957 | 3262 | 3611 | 3990 | 4435 | 5001 | 5539 | 6006 | 6726          |

Fig.4 Loss of retail sales growth in the first and second quarter of 2020

The first quarter
The second quarter
Tourism is a highly environmentally sensitive industry, especially during the Spring Festival when tourism peaks [2]. According to historical data, more than 450 million trips are expected to be made during the Spring Festival in 2020. Affected by the epidemic, the tourism market is almost completely suspended and frozen. According to statistics, the short-term direct losses amount to more than 500 billion yuan, and the annual tourism revenue loss will reach more than 1.6 trillion yuan. As the world's largest source of outbound tourists, the decrease in the number of Chinese tourists during the Spring Festival alone has caused a loss of nearly 1 trillion yuan to the global tourism economy [2]. As the epidemic spreads around the world, the global travel market will suffer even more.

Based on February 20, 2020 China tourism academy released by the China tourism economic blue book No. 12 " , though during the Spring Festival COVID - 19 outbreak caused a huge impact on the tourism economy, China's economic fundamentals support the development of tourism will not change, the continued growth of mass tourism fundamentals have not changed, 2020 tourism economy overall not too pessimistic [3]. As the global epidemic is still continuing and the health emergency rating of international concern has not been eliminated, the negative growth of domestic tourists and income and outbound tourists has reached about 20% and above, respectively. The epidemic situation in China has been effectively controlled, laying a solid foundation for the sustained and stable development of the domestic tourism market. According to the investigation of China Tourism Academy, the epidemic has no significant impact on per capita travel rate and per capita travel expenditure, so it is expected to see a recovery growth after the epidemic [3].

### 3.3. Catering Industry

The catering industry is a typical industry where people gather together. Under the epidemic prevention and control measures, all kinds of parties and banquets during the 2020 Spring Festival have almost been cancelled. Restaurants, food stalls and food courts in provinces and cities across the country have been closed. Except for some catering enterprises that operate group meals and single restaurants, most catering enterprises choose to close their stores during the epidemic period, as shown in Table 7 below.
Table 7 Operation of coVID-19 restaurants during the Spring Festival in 2020

| closures                         | going concern          |
|----------------------------------|------------------------|
| Close all stores                 | Store maintenance      |
| proportion                       |                        |
| 73%                              | 7%                     |
| Close less than 80% of stores    |                        |
| 8%                               |                        |
| Close less than half of its stores |            |
| 7%                               |                        |
| Store maintenance               |                        |
| 7%                               |                        |

Since most catering enterprises have more food stocks before the Spring Festival, most of these losses are net losses and cannot be backfilled after the epidemic [2]. According to the National Bureau of Statistics, the national catering revenue in 2019 was 4.672.1 trillion yuan, of which consumption during the Spring Festival accounted for 15.5 percent. Compared with the same period last year, affected by the epidemic, Spring Festival. According to the Evergrande research institute, the COVID-19 caused a loss of about 500 billion yuan in retail sales of the catering industry within just 7 days of the Spring Festival [4].

![Fig.6](image)

Fig.6 Loss of business income of Chinese catering enterprises during the Spring Festival epidemic in 2020

In the catering industry, small and medium-sized enterprises occupy the main part, and their anti-risk ability is more vulnerable. Due to the sudden outbreak of the epidemic, catering enterprises have to bear large costs, including the loss of expired supplies, fixed expenses such as rent and labor costs, and procurement costs of epidemic prevention and control supplies.

Due to the uncontrollable COVID-19 epidemic during the Spring Festival, the number of residents' takeout orders has decreased, the management of external sales personnel in all regions is strict, and the commission rate of the takeout platform is relatively high, so the takeout delivery business has not had an obvious effect on the catering business.

As an industry with strong dependence on cash flow, most enterprises invest a large amount of cash before the Spring Festival in the payment of wages and bonuses and the operation of preparing vegetables and reserves during the Spring Festival. The poor operation during the Spring Festival is likely to make the catering enterprises fall into the state of capital chain tension.
4. Conclusion and Development Suggestions

Based on the above analysis, the tertiary industry was hit hard in the first quarter of 2020 under the impact of COVID-19. Due to the industrial characteristics, the industries directly affected by COVID-19, such as retail, tourism, and catering industries, have seen their overall output value drop significantly. With the help of the grey prediction model, the actual value was compared with the predicted value without epidemic situation. The results showed that the epidemic situation had a great impact on the development of integrated service industry in the first quarter, especially during the Spring Festival. According to the data, as the epidemic situation in China was effectively controlled within a short period of time, the overall output value of the tertiary industry in the second quarter rebounded steadily. The depressed situation of the retail trade, tourism, and catering industry all showed a relatively obvious recovery trend after the government issued various policies and guidance. Different industries also took advantage of the epidemic to upgrade and transform their industries.

The epidemic has accelerated the transformation of retail business model. With the help of emerging technologies such as 5G, artificial intelligence, and big data, the demands of unmanned delivery, sinking market, and "home economy" are gradually reshaping the future business model [5]. Referring to the changes in economic development before and after SARS in 2003, "compensatory consumption" after the epidemic will, to a certain extent, ease the impact on the annual consumption growth [5]. Enterprises in the retail industry that depend too much on offline business should consider more to combine offline and online business. In the context of the normalization of epidemic prevention and control, online technology should be used to promote and market products, and the offline sales model should be reasonably combined.

According to the analysis of tourism data in 2019, mass tourism is growing continuously. The impact of the epidemic on tourism is temporary, and the rigid tourism consumption fundamentals and medium- and long-term trends will not change. In the latter part of the second quarter, domestic tourism has gradually returned to normal. Combined with history and international experience, when the epidemic is over, domestic tourism may recover quickly with the initial intention to travel and "retaliatory consumption". As the global epidemic continues to spread, the recovery period for the inbound tourism market will be longer than for the domestic market. Only with the end of the epidemic can the offline commercial service markets related to tourism, such as supporting performances and hotels, be gradually restored [3].

Although the catering industry was hit hard during the 2020 Spring Festival, a series of measures were taken by the government to speed up the transformation of traditional catering models. It is necessary to further strengthen online marketing and actively develop the takeaway business. According to the China Cuisine Association, take-out food accounted for more than 60 percent of catering income during the epidemic. Under normal circumstances, the proportion is between 10%-15% [4]. At the same time, in order to better cooperate with the epidemic prevention work normalization, it is suggested that more catering enterprises pay attention to the lives of the people at home to prevent the epidemic. Establish community food stations to accurately target consumer groups.

References

[1] Liu Xiangming, HAN Zhonggeng. Evaluation model of the impact of SARS epidemic on some economic indicators [J]. University Mathematics, 2005(03):13-17.
[2] Li zm, sheng f f. impact of covid-19 on China's industry and consumption and response [J]. Jiangxi social sciences, 2020, 40(03):5-15. (in Chinese)
[3] China Tourism Academy. Blue Book of China's Tourism Economy No.12[R]. Beijing :2020
[4] China Cuisine Association. Investigation and Analysis report on the Operation status and Development Trend of China's catering Industry during CoVID-19 epidemic in 2020 [R]. Beijing :2020
[5] Zheng jianhuai, fu yifu, tao jin. Impact of covid-19 on consumer economy and countermeasures [J]. Consumer economy, 2020,36(02):3-9.
[6] Zhu Shiyan, Liu Chongxian. Analysis on the impact of COVID-19 on China's lifestyle Service Industry and countermeasures [J]. Times Economy and Trade, 2020(16):52-53.

[7] Li Xintong, Fang Yi. Study on the Impact of COVID-19 on China's economy and Countermeasures [J]. Journal of Changchun Institute of Finance, 2020(04):78-87.

[8] Rao Fangli. Analysis of the economic impact of COVID-19 [J]. Cooperative Economics and Technology, 2020(15):27-29.

[9] Li Wenlong. Comparison between COVID-19 and SARS and its impact on China's economy [N]. China Business News, 2020-02-05(A11).

[10] Li Yunjing, Liao Fei. Application of Grey Forecasting Model in the prediction of per capita REGIONAL GDP in Heilongjiang Province [J]. Industrial Innovation Research, 2020(12):44-45.

[11] Zhou Xinhui, Li Yuzhe, Li Fufu. Impact Assessment and Countermeasures of COVID-19 on Small and Medium-sized service enterprises -- Analysis and Prediction based on regression Algorithm Optimization Model [J]. Economic Review, 2020(03):101-117.

[12] Zhang Xia-heng. Impact of covid-19 on micro, small and medium enterprises in China and response to it [J]. China circulation economy, 2020, 34(03):26-34.

[13] Liang Peng, Xing Lixia. Study on the Impact of COVID-19 epidemic on catering Industry and Countermeasures [J]. Times Economy and Trade, 2020(07):8-12.

[14] Li Chunhua. Statistical Considerations on the Impact of SARS on China's Economy [J]. Journal of Datong Vocational and Technical College, 2004(04):8-11.