

Analysis and Research on the Influencing Factors of Regional CPI Based on CVM-AHP Coupling Perspective

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Abstract. The consumer price index (CPI) is a statistical indicator to measure the macroeconomic development of a region. Studying the influencing factors of regional CPI is helpful to deeply explore the mechanism of CPI change, and then help to measure inflation, national economic accounting, and contract indexation adjustment. In this paper, the coefficient of variation method (CVM) and analytic hierarchy process (AHP) is used to determine the subjective and objective weights of the evaluation factors, and the coupling weights are calculated based on the Lagrange multiplier method. Shanghai, China, is selected for empirical analysis to evaluate the suitability of CPI influencing factors in the study area. The results show that regional CPI is closely related to population size, population density, the proportion of the elderly population, urban resident population, GDP, per capita disposable income, PPI, and fixed asset investment. Among them, GDP, per capita disposable income, and fixed asset investment have the most prominent impact on CPI. The proportion of the elderly population and PPI have a more obvious impact, and the impact of population size, population density, and urban resident population is not obvious. The research on the influencing factors of regional CPI in this paper is of great practical significance to explore the causes of China's inflation and formulate reasonable macroeconomic policies.

Keywords: CPI; influencing factors; CVM; AHP; lagrangian multiplier method.

1. Introduction

According to the economic operation data released by the National Bureau of Statistics of China in the first half of 2022, in June, China's national CPI was flat, up 2.5 % year-on-year; on average, CPI rose 1.7 % from January to June[1]. Since CPI is closely related to people's material living standards, the continuous rise of CPI has become a hot topic in academic circles. Analyzing the influence mechanism of regional multiple factors on CPI is conducive to the choice of macroeconomic policy tools, thus stabilizing prices and improving people's living standards. At present, there are many types of research in this field.

Xin [2] takes the monthly year-on-year data of PPI and CPI in Shandong Province of China as the research object, studies the mean spillover effect between the two by establishing the VAR model, and studies the volatility spillover effect between the two by establishing BEKK-GARCH model. Xie et al. [3] established a time series model, through the empirical analysis of China's CPI value, established a better statistical prediction model to reflect the CPI change rule. Liu [4] used the BIC criterion to determine the number of sequence change points and estimated the location of change points according to the multi-point analysis theory based on the linear time accurate division method, and discussed the influencing factors and fluctuation characteristics of the CPI index change points. Chen [5] used the VAR model and impulse response function to conduct empirical research and concluded that economic growth and the increase in money supply have accelerated the rise in prices. Wang and Liu [6] used stationarity test and regression analysis to measure the CPI structure factors in Macao, China, and established a reasonable influence CPI structure model to analyze the causes of economic overheating and inflation in Macao, and put forward three countermeasures and suggestions. Zhao [7] used the time series data of relevant economic indicators from 2001 to 2017 to carry out quantitative and qualitative analysis on the influencing factors of CPI in Chengdu through the

principal component analysis method in multivariate statistical analysis, providing a corresponding theoretical basis and decision-making reference for the government to maintain CPI stability.

In this paper, regional population and economy are taken as the main level in the selection of regional CPI influencing factors, and the objective regional characteristics such as regional geographical location, topography, and topography are not considered, so there are some research loopholes. At the same time, in order to ensure the robustness of the results, this paper first constructs the index system of regional CPI influencing factors from the aspects of population, economy, and environment, and uses the coefficient of variation method (CVM) and the analytic hierarchy process (AHP) to determine the subjective and objective weights of the evaluation factors respectively. Based on the Lagrange multiplier method, the coupling weight is calculated, which avoids the error caused by the single method, and the conclusion will be more comprehensive and effective. The research in this paper is helpful to broaden the cognitive perspective of CPI, suppress the level of inflation, and maintain the steady and healthy development of the national economy.

2. Construction of Index System of Regional CPI Influencing Factors

2.1 Population aspects

Population determines the production of labor and national consumption, to create and consume social material wealth and spiritual wealth of an important role. In recent years, with the disappearance of China's "demographic dividend," the age structure of the population has changed. According to the seventh national census bulletin of China's National Bureau of Statistics, the population aged 15-59 accounted for 63.35 % of the national population, down 6.79 percentage points from the sixth census, and the population over 60 years old accounted for 18.70 %, up 5.44 percentage points from the sixth census. According to the life cycle hypothesis, rational consumers plan the proportion of their income spent on consumption and savings based on their life expectancy. The general rule of consumption is that during the youth period, due to low disposable income and high expected future income, income is often used for consumption and even debt consumption; in middle age, due to the need to repay debts at a young age and the need to save for old age, the proportion of consumption in income will decrease; after retirement income declines, consumption will be greater than income. At the same time, at different ages, the supply-side labor costs are different, and the consumption structure of demand-side consumers will also change, which will have an impact on CPI. Moreover, due to the different consumption levels and consumption structures of the urban population and the rural population, the urbanization rate of the regional population will also affect the consumer price index. Therefore, based on the above conclusions, this paper selects population size (X_{11}), population density (X_{12}), the proportion of the elderly population (X_{13}), and urban resident population (X_{14}) to measure the impact of the population on CPI.

2.2 Economic aspects

The changes in economic factors will have a direct impact on regional CPI. From the perspective of GDP, if the regional GDP shows positive growth and the value is large, indicating that the regional economy is in a relatively rapid development state, the market money demand increases, and the government will regulate monetary policy such as printing money. If the money supply exceeds demand, it will cause inflation. CPI is a measure of inflation, changes in GDP will drive the CPI changes in varying degrees. At the same time, the good trend of economic development is often accompanied by the increase in per capita disposable income of residents and the improvement of residents' consumption level, which has an impact on CPI.

From the perspective of the producer price index (PPI), PPI reflects the price changes in the production field and has a certain transmission effect on CPI. From the law of price transmission, first, the price rise of coal, oil, electricity, and so on is transmitted to agricultural means of production, promoting the price rise of agricultural products, and then transmitted to food prices, causing CPI to rise; second, rising prices of raw materials caused by rising costs of industrial products, the

conduction to the rise in CPI; third, the rise in the prices of coal and fuel has led to an increase in the prices of water and electricity consumed by residents, which has led to an increase in CPI.

From the perspective of investment, the investment in fixed assets of the whole society is a comprehensive index reflecting the scale, speed, and proportion of fixed asset investment, which has a significant pulling effect on regional economic development. According to previous literature, the faster the growth of fixed asset investment, the faster CPI changes; the consumer price index is very sensitive to the impact of the lag of fixed asset investment. Therefore, this paper selects GDP (X₂₁), per capita disposable income (X₂₂), PPI (X₂₃), and fixed asset investment (X₂₄) to measure the impact of the economy on CPI. In summary, the CPI impact index system constructed in this paper is shown in table 1 :

Table 1 CPI influencing factors index system

First-grade indexes	Second-grade index	Indicator units	References
Population (X1)	Population size (X11)	A Million people	[8]
	Population density (X12)	People / km ²	[9]
	The proportion of old (X13)	%	[10]
	Urban resident population(X14)	A Million people	[11]
Economy (X2)	GDP(X21)	Billion yuan	[12]
	Disposable income (X22)	Yuan	[13]
	PPI(X23)	-	[14]
	Fixed investments (X24)	Billion yuan	[15]

3. CVM Method

The coefficient of variation method (CVM) is an objective weighting method that directly uses the information contained in each index to calculate the weight of the index. Coefficient of variation CV value formula is as follows: $cv = \text{standard deviation} / \text{average}$. If the coefficient of variation CV value is larger, it means that the greater the volatility of the index data, indicating that the greater the information carried, and thus the weight will be greater. In this paper, the coefficient of variation method is used to objectively weigh all the secondary indicators in the regional CPI influencing factors. The main calculation steps are as follows:

STEP1: Assuming that there are n evaluation indicators and m evaluation objects, the evaluation matrix X of the indicator can be constructed, where x_{ij} represents the characteristic data of the j th ($j = 1, 2, 3, \dots, m$) evaluation indicator of the i th evaluation object.

STEP2: Calculate the average value of the i th indicator $\bar{x}_i$ is :

$$\bar{x}_i = \frac{1}{m} \sum_{j=1}^m x_{ij} \quad (1)$$

STEP3: Calculate the standard deviation of the i th index σ_i :

$$\sigma_i = \sqrt{\frac{1}{m} \sum_{j=1}^m (x_{ij} - \bar{x}_i)^2} \quad (2)$$

STEP4: Calculate the coefficient of variation of the i th index v_i :

$$v_i = \frac{\sigma_i}{\bar{x}_i} \quad (3)$$

STEP5: Normalize the obtained coefficient of variation and calculate the objective weight of the i th index w_{li} :

$$w_{li} = \frac{v_i}{\sum_{i=1}^n v_i} \quad (4)$$

4. AHP Method

Analytic Hierarchy Process (AHP) is an analytical method that applies network system theory and multi-objective comprehensive evaluation methods to make hierarchical weight decisions. It is a qualitative and quantitative decision analysis method to solve multi-objective complex problems. This paper constructs the index system of regional CPI influencing factors, compares the importance of each factor, establishes the weight matrix, and empowers each index. Its main calculation steps are as follows:

STEP1: Building a hierarchical structure model. According to the decision-making objectives, guidelines, and programs, according to the relationship between them is divided into the highest layer, the middle layer, and the lowest layer, draw a hierarchical structure diagram. If there are too many criteria, the sub-criteria layer should be further decomposed.

STEP2: Building a comparative judgment matrix Starting from the second layer of the hierarchical structure model, for the same layer of each factor belonging to the previous layer, the nine-level scale method is used to digitally represent the relative importance of all evaluation factors, and compare them with each other to construct a judgment matrix A until the lowest level. a_{ij} represents the importance of the indicator element i relative to j .

$$a_{ij} = \frac{1}{a_{ji}} \quad (5)$$

STEP3: Calculating the Index Weights and Ranking the Overall Level. Calculate the approximate value of the weight vector ($j=1,2,\dots,n$):

$$w_j = \sqrt[n]{\prod_{i=1}^n a_{ij}} \quad (6)$$

Normalization :

$$w_{2j} = \frac{w_j}{\sum_{k=1}^n w_k} \quad (7)$$

5. Coupling weight calculation

For each index, the objective weight w_{li} and the subjective weight w_{2i} are combined, and the Lagrangian multiplier method is used to optimize the coupling weight [16] :

$$w_i = \frac{(w_{li} w_{2i})^{0.5}}{\sum_{i=1}^m (w_{li} w_{2i})^{0.5}} \quad (11)$$

Through the above steps, the corresponding weights of each secondary index of the regional CPI influencing factor index system under different methods can be determined, and finally, the coupling weights can be obtained.

6. Empirical analysis

6.1 Research object selection and data collection

Shanghai is the largest city in China and the economic, financial, trade, and shipping center of mainland China. Its GDP ranks first in Chinese cities and second in Asian cities. After the reform and opening up, along with the continuous advancement of economic and social reform in Shanghai, the price reform in Shanghai has been deepening, and gradually established a price formation mechanism in which prices are mainly determined by the market. With the transformation of the system and the take-off of the economy, in the past four decades, Shanghai's CPI has also experienced many fluctuation cycles with different characteristics, which has attracted wide attention from the domestic and even the international community. Studying the influencing factors of Shanghai CPI is of great significance for regulating macroeconomic policies, stabilizing prices, and suppressing inflation.

Based on the statistical yearbook of the Shanghai Municipal Bureau of Statistics and the China Economic Database, this paper selects the secondary index data of Shanghai from 2010 to 2020. Among them, demographic data are based on the sixth and seventh censuses and descriptive statistics are given in Table 2:

Table 2 Descriptive statistics of secondary indicators in Shanghai

Index name / unit	Max	Min	Mid	Mean
X11/ million people	2488.36	2398.50	2467.06	2460.92
X12/ People / km2	3925.00	3783.00	3897.50	3881.67
X13/%	36.10	25.70	31.06	31.34
X14/ million people	2220.94	2115.78	2136.00	2147.51
X21 /billion yuan	38700.58	21305.59	36011.82	30242.05
X22/ yuan	72232.00	40188.00	49867.00	5526.56
X23/-	98.90	92.90	96.60	96.40
X24/ billion yuan	8837.47	5254.38	6755.88	6860.76

6.2 Numerical calculation

Based on the CVM and AHP algorithm constructed above, the CVM weight is calculated based on MATLAB, and the AHP weight is obtained by constructing the judgment matrix. Finally, the coupling weight is obtained based on the Lagrange multiplier method, as shown in Table 3. The AHP judgment matrix is shown in Equation (11) :

$$A = \begin{bmatrix} 1 & 1 & \frac{1}{4} & \frac{1}{2} & \frac{1}{5} & \frac{1}{5} & \frac{1}{3} & \frac{1}{4} \\ 1 & 1 & \frac{1}{4} & \frac{1}{3} & \frac{1}{4} & \frac{1}{4} & \frac{1}{3} & \frac{1}{4} \\ 4 & 4 & 1 & 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{2} & \frac{1}{3} \\ 2 & 3 & 1 & 1 & \frac{1}{4} & \frac{1}{3} & 1 & \frac{1}{3} \\ 5 & 4 & 3 & 4 & 1 & \frac{3}{2} & 3 & 2 \\ 5 & 4 & 3 & 3 & \frac{2}{3} & 1 & 3 & \frac{3}{2} \\ 3 & 3 & 2 & 1 & \frac{1}{3} & \frac{1}{3} & 1 & \frac{1}{2} \\ 4 & 4 & 3 & 3 & \frac{1}{2} & \frac{2}{3} & 2 & 1 \end{bmatrix} \quad (11)$$

Table 3 Weight table of each index

Name of indicator	Objective weights	Subjective weights	Coupling weights
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X11	0.014	0.038	0.028
X12	0.014	0.038	0.028
X13	0.152	0.086	0.118
X14	0.020	0.080	0.042
X21	0.278	0.261	0.280
X22	0.274	0.220	0.254
X23	0.028	0.100	0.055
X24	0.221	0.177	0.205

In order to visualize the results of this paper, the weight map based on Origin is shown in Figure 1 :

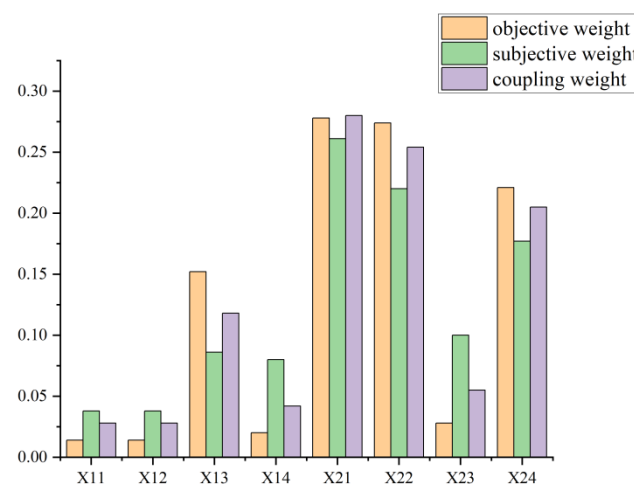


Fig. 1 Secondary index weight histogram

On the objective weight, GDP accounted for the largest weight, reaching 0.278 ; the second is the per capita disposable income, reaching 0.274; third is the fixed asset investment, reaching 0.221; the fourth is the proportion of the elderly population, reaching 0.152; the fifth is PPI, accounting for 0.028; the sixth is the urban resident population, accounting for 0.020; the proportion of population size and population density was the lowest at 0.014.

On the subjective weight, GDP accounts for the largest weight, reaching 0.261 ; the second is the per capita disposable income, reaching 0.220 ; third is the fixed asset investment, reaching 0.177; the fourth is PPI, reaching 0.100; the fifth is the proportion of the elderly population, accounting for 0.086; the sixth is the urban resident population, accounting for 0.080; the proportion of population size and population density was the lowest at 0.038.

After coupling, GDP has the largest weight, reaching 0.280; the second is the per capita disposable income, reaching 0.254; the third is the fixed asset investment, reaching 0.205; the fourth is the proportion of the elderly population, reaching 0.118; the fifth is PPI, accounting for 0.055; the sixth is the urban resident population, accounting for 0.042; population size and population density were the lowest at 0.028. The coupling results better integrate the subjective and objective gap of the building, making the calculation results more reasonable and effective.

6.3 Analysis and suggestions

6.3.1 First-level index weight results analysis

From the weight distribution of the first-level index, it can be seen in figure 2 that the weight of X1 is 0.216, the weight of X2 is 0.784, and the weight of X2 is significantly greater than that of X1, indicating that the impact of economic factors on CPI is far greater than that of population. In this regard, in order to reasonably regulate the CPI and ensure the smooth operation of the national

economy, the government should actively implement economic policies in response to the uncertain fluctuations in market prices. It is necessary to carry out more comprehensive supervision of market prices in the process of economic development and to strictly control commodity production prices, especially the necessities of life, in some important and special periods. At the same time, in view of the continuous transformation of the population development model to modernization and the changing social consumption structure, the government should appropriately adjust the household registration policy, fertility policy, etc., reasonably control the population size, effectively respond to the trend of population aging, develop an industrial system that adapts to the consumption structure of each age stage, and meet the new consumption demand brought by the transformation of the population model.

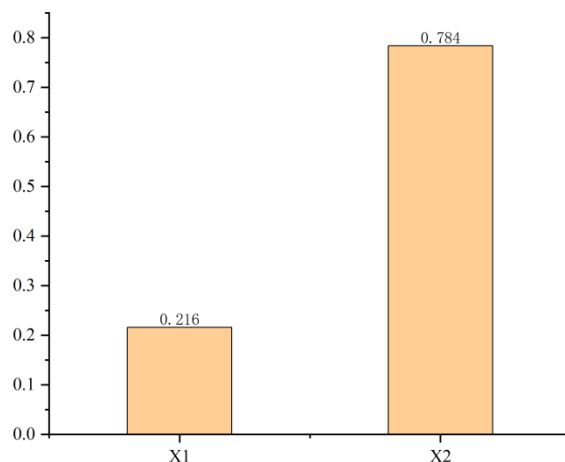


Fig. 2 First-level index weight histogram

6.3.2 Analysis of secondary index weight results

Based on the coupled weights, we find that changes in GDP, per capita disposable income and fixed asset investment have the most prominent impact on CPI. According to the quantity theory of money in macroeconomics, the price level and the value of money depend on the quantity of money issued. In general, money supply is positively correlated with GDP. From 2012 to 2020, Shanghai's GDP continued to rise and the money supply continued to increase. When the excessive money supply caused the purchasing power of the payable money to be greater than the money supply, currency depreciation and general price increases occurred, causing CPI to rise. According to the wage-driven inflation theory, in an imperfectly competitive labor market environment, excessive wage increases push up production costs, which in turn drives up the overall price level. From 2012 to 2020, Shanghai's per capita disposable income increased rapidly, reflecting the rising wages of residents and pushing up CPI. At the same time, the increasing investment in social fixed assets not only facilitates people's lives to a certain extent but also is conducive to the upgrading of production equipment and the improvement of production level, thus changing the social production and consumption structure and transmitting to the change of CPI.

Secondly, the influence of the proportion of the regional elderly population and PPI on CPI is also obvious. The increase in the proportion of the elderly population has led to the adjustment of production structure on the supply side, especially in related industries such as food, clothing, health care, housing, transportation, and communications, while changes in the consumption structure of residents have affected CPI from the consumption side. The change of PPI reflects the price fluctuation in the production field, which is transmitted to the downstream industry through the industrial chain and spread, and finally affects consumer goods, causing the change of CPI.

Finally, the impact of regional population size, population density, and urban resident population on CPI is not obvious. Compared with the large base, Shanghai's population size, population density, and urban resident population changed slightly from 2012 to 2020. At the same time, Shanghai's

population indicators are more suitable for its economic development needs, so its short-term small changes have no obvious impact on CPI.

In summary, according to the different effects of different indicators on CPI, this paper puts forward the following suggestions :

(a) Deepen the supply-side structural reform, promote the optimization and upgrading of industrial structure, meet the changing demand structure, and promote the effective connection between supply and demand.

(b) Play a decisive role in market prices, straighten out the product price formation mechanism, strengthen tax leverage adjustment, stabilize prices, and ensure the stable and healthy development of the national economy.

(c) Improve the income distribution system, reasonably control the income growth rate, ensure the synchronization of residents' income growth and economic development, narrow the income gap between urban and rural residents, and take into account fairness and efficiency.

(d) Improve the social pension service system, strengthen the construction of pension infrastructure, improve relevant industrial policies, and solve the contradiction between the supply and demand of pensions.

7. Conclusion

(a) From the results of the first-level index weight, $X_1 > X_2$, the economic level index weight is greater than the population level, which proves that the economic level index has a more direct and obvious impact on CPI. Therefore, the government should focus on the adjustment of economic policies in the process of regulating CPI, while taking into account the changes in consumption structure caused by changes in population structure.

(b) From the results of the second-level index weight, $X_{21} > X_{22} > X_{24} > X_{13} > X_{23} > X_{14} > X_{12} = X_{11}$, indicating that regional GDP, per capita disposable income, and fixed asset investment have the most prominent impact on CPI. The proportion of the elderly population and PPI are more obvious, and the impact of population size, population density, and the proportion of the urban population is not obvious. Therefore, the regulation of CPI must focus on regional economic development trends and income distribution, while reasonably regulating industrial policies and taking into account demographic changes.

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