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Measurement of Inflation in China: An Empirical Study of a VAR Model Based on the EWM Indicator System

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Abstract: *Inflation is an important phenomenon in the national economy, and central banks have made it one of their tasks to control inflation. The core research object of this paper is the causes of inflation in China since it entered the 21st century, and the Entropy-weighting Method is used to construct a comprehensive indicator system, including 5 different factors contributing to inflation, then analyze it using a VAR model. The following conclusions are drawn: demand-pull inflation in China is more influential than cost-push inflation, and the expectation factor is an important cause of inflation.*

Keywords: *VAR model, Inflation, Entropy-Weighting Method*

1. Introduction

Inflation has always been a hot topic in the academic field, highlighting its great impact on the economy. Since the beginning of the 21st century, China has kept its inflation rate below 5%, referred to as "moderate inflation" by Feng Ke (2007) [1]. Yet after the outbreak of COVID-19, central banks of several major countries have conducted loose monetary policy to stimulate the economy, bring down the unemployment rate, and boost consumption, however, accompanied by a higher inflation rate. The inflation rate (measured by CPI) of the US has jumped from about 1% in 2019 to more than 6% as of March 2023 and even the maximum value has been over 9.1% in June 2022, which is a dangerous signal to the monetary policymakers. In response, the Fed raised interest rates 7 times in 2022 with the cumulative increase adding up to 425bp. Yet Fed's tight monetary policy didn't drag the inflation back to the "safe zone", leading to the overvaluation of the dollar. This eventually led to the devaluation of the RMB, known as inflation.

Another inflationary pressure on China is the rise in commodity prices and international energy prices, caused by the Russia-Ukraine war. Equally, China's economy is recovering at a relatively fast pace from the epidemic, following an expansionary monetary policy that causing inflation objectively. In summary, China is dealing with unprecedented inflationary pressures, but at the same time needs to maintain economic growth. This is where it is important to identify the factors that cause inflation.

Inflation has been extensively studied by scholars, who have proposed various theories to explain its causes and consequences. Keynesianism believes that the main factors affecting the demand for money are income and interest rates. Changes in the quantity of money supply would affect the level of interest rates, which in turn affects the quantity of money demand, and thus the demand for investment and consumption, while changes in effective demand, with full employment, affect the price of goods. Monetarism proposes that the total amount of money consumed by an economy depends on the total amount of money on hand, and that inflation is caused by a higher rate of money supply than economic growth. Milton Friedman believes that "Inflation is always and everywhere a monetary phenomenon". He also stressed that controlling inflation relies on the government's fiscal and monetary policies. Neo-Keynesian sees three forms of inflation, namely demand-pull inflation, cost-push inflation, and inherent inflation. William Phillips, on the other hand, came up with the famous Phillips curve, which summarizes the relationship between unemployment and inflation moving in opposite directions. The supply school believes that inflation must be caused by an excess supply of money and a shortage of demand, and that when money supply and demand increase at the same time, it does not lead to inflation.

The innovation of this paper is that a comprehensive indicator system will be constructed using the Entropy-Weighting Method (EWM), which can systematically identify certain causes of inflation and is better suited for analyzing the causes of inflation in China from a macro perspective.

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The structure of this paper is as follows: (1) Select data and construct an indicator system using EWM (2) Conduct Granger test, Johansen cointegration test, etc. (3) Determine the lag order to construct a VAR model, conduct impulse response analysis and variance decomposition analysis (4) Draw conclusions and provide policy recommendations.

2. Related works

For inflation in China, most studies have considered cost-push and demand-pull factors. Some scholars believe that structural inflation, represented by fluctuations in primary product prices and asset prices, has become an important manifestation (Qiu Yilin and Liang Si, 2022) [2]. Second, for cost-push inflation, scholars are not only concerned with traditional food, clothing, transportation and communication prices, but also with financial services, real estate prices, etc. Some scholars have considered the impact of asset price volatility on inflation through real estate, stocks, and other channels (Zhang Lin, 2020) [3]. Studies have shown that China's mandatory foreign exchange settlement system and complex bank loan approval process will increase market inflation (Luo Xiangxi, 2018) [4]. Demand-pull remains an important factor in inflation. (Zhou Xiaochuan, 1988) [5]. Similarly, policy factors and financial factors need to be examined in focus (Duan Ruijun, 2008) [6]. In summary, the factors affecting inflation can be divided into five categories of factors: demand-pull factors, cost-push factors, structural factors, financial factors, and inflationary expectations.

For the study of inflation, many scholars have chosen to study it through the Phillips curve (Chen Xuebin, 1996[7]; Chen Yanbin, 2008[8]). Most scholars, on the other hand, analyze it through econometric models such as VAR models (Feng Beilin et al., 2006) [9] or linear regression (Fu Dan et al., 2009) [10]. With the advancement of information technology, some scholars have introduced machine learning to analyze the causes of inflation. Some studies have identified factors affecting inflation using SHAP-valued explanatory methods and various nonlinear machine learning methods such as SVR (Xiao Zhengyan et al., 2022) [11].

However, most of the available studies have directly linked various economic variables to inflation and have not been able to measure the five different types of factors mentioned above separately, which makes it difficult to assess the causes of a certain inflation in an integrated manner. Therefore, this paper will classify the various economic indicators and calculate the weights to compile a comprehensive index system.

The choice of methods for calculating the weighting can be divided into subjective and objective methods. Subjective methods include the AHP hierarchical analysis method and the superior order diagram method, which are used in fields such as performance evaluation (Deng Xue et al. 2012) [12], but they all need to rely on expert ratings. The objective method is more comparable for different indicators, and the Entropy-Weighting Method is an objective method to calculate weights, which applies the information entropy theory to weight assignment and is widely used in fields such as risk assessment (Yi Ruolan, 2022) [13] and investment decision making (Lu Anxuan, 2021) [14]. In this paper, the Entropy-Weighting Method (EWM) will be selected to compile a comprehensive index of the five aforementioned inflation factors and subsequently construct a VAR model for analysis, so as to systematically identify the factors affecting inflation.

3. Indicator System Construction

3.1. Data Selection

Drawing on Xiao Zhengyan's study [11], the demand factors are divided into investment demand, domestic consumption demand, foreign consumption demand, and Import investment demand, which correspond to Fixed asset investment completion, Total retail sales of social consumer goods, Export amount, Amount of foreign direct investment. Cost factors include industrial producer purchase price index (PPI), Basket Price: Crude Oil, corresponding to raw material price factors, and energy price factors. Food prices are chosen to measure structural inflation because the primary sector, to which food belongs, is weak in today's industrialized society and can reflect structural imbalances in the economy. Structural factors include the CPI (food), the Average price of live pigs in 22 provinces and cities in China as well as the UN Food and Agriculture Price Index, corresponding to domestic and international food prices. Financial factors include M2, Real estate development investment completion, RMB effective exchange rate and SHIBOR (Shanghai Interbank Offered Rate), and the above indicators can directly or indirectly

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reflect the effect of monetary policy and financial market impact. Finally, the expectations factor uses the price expectations index compiled by the People's Bank of China. The indicator system is shown in Table 1.

Table 1: Indicator system.

Influencing Factors	Economic Indicators	Abbreviations	Data source
Demand factors	Fixed asset investment completion	ASI	National Bureau of Statistics
	Total retail sales of social consumer goods	CSU	National Bureau of Statistics
	Export amount	EXO	General Administration of Customs
	Amount of foreign direct investment	INV	General Administration of Customs
Cost Factors	Basket Price: Crude Oil	OIL	OPEC
	PPI	PPI	National Bureau of Statistics
Structural Factors	CPI: Food	CPF	National Bureau of Statistics
	UN Food and Agriculture Price Index	UNA	Food and Agriculture Organization of the United Nations
	The average price of live pigs in 22 provinces and cities in China	PIG	China Breeding Pig Information Network
Financial Factors	M2	M2	People's Bank of China
	Real estate development investment completion	RES	National Bureau of Statistics
	RMB Real Effective Exchange Rate Index	EXC	Bank for International Settlements
	SHIBOR	SHB	China Foreign Exchange Trading Center
Expected Factors	Future Price Expectation Index	FEX	People's Bank of China

All indicators are calculated at monthly intervals. For high-frequency indicators, such as PIG, SHB uses a weighted average to calculate the indicator for the current month. For low-frequency indicators, such as FEX, the cubic interpolation approach is used to calculate the current month's indicators at quarter intervals. The data span from March 2007 to December 2022 and are indexed to March 2007 as the base period.

3.2. Description of the Entropy-Weighted Method (EWM)

Information entropy draws on the concept of entropy in thermodynamics, and according to the basic principles of information theory, information is a measure of the orderliness of a system, and entropy is a measure of the degree of system perturbation. According to the definition of information entropy, the entropy value can be used to evaluate the degree of variance of a given indicator if it is given. If all indicators have the same value, the indicator has no effect on the overall evaluation. Therefore, the information entropy tool can be used to calculate the weight of each indicator and provide a basis for the comprehensive evaluation of multiple indicators. Information entropy is measured in bits, and the basic formula is as follows.

$$H(X) = \sum_i P(x_i) I(x_i) = -\sum_i P(x_i) \log_b P(x_i) \quad (1)$$

P is the probability mass function.

3.3. Empirical Calculations

Standardize the data of each indicator. Suppose that K indicators $X_1, X_2 \dots X_K$ are given, where $X_i = \{x_1, x_2 \dots x_n\}$. Assuming that the values of each indicator are $X_1', X_2' \dots X_K'$,after standardization, then

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \quad (2)$$

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Calculate the weight of each indicator.

$$Y_{ip} = \frac{x'_{ip}}{\sum_{i=1}^{m} x'_{ip}} \tag{3}$$

Calculate the information entropy of the p[th] metric.

$$E_p = -ln(m)^{-1} \sum_{i=1}^{m} \left(Y_{ip} \times lnY_{ip}\right) \ (0 \le E_p \le 1) \tag{4}$$

Calculate the information entropy redundancy of the p[th] metric.

$$D_p = 1 - E_p \tag{5}$$

Calculate the weight of the p[th] indicator.

$$W_p = \frac{D_p}{\sum_{p=1}^{n} D_p} \tag{6}$$

The empirical results are shown in Table 2.

Table 2: Empirical results.

Influencing Factors	Indicators	E_p	D_p	W_p
Demand factors	ASI	0.925930948	0.074069052	28.2262%
	CSU	0.927122368	0.072877632	27.7721%
	EXO	0.942348144	0.057651856	21.9699%
	INV	0.942185816	0.057814184	22.0318%
Cost Factors	OIL	0.974868089	0.025131911	48.3570%
	PPI	0.973160327	0.026839673	51.6430%
Structural Factors	CPF	0.979397767	0.020602233	18.7813%
	UNA	0.96350779	0.03649221	33.2668%
	PIG	0.947398803	0.052601197	47.9519%
Financial Factors	M2	0.949342859	0.050657141	29.6188%
	RES	0.933996823	0.066003177	38.5914%
	EXC	0.975191089	0.024808911	14.5055%
	SHB	0.970438617	0.029561383	17.2843%
Expected Factors	FEX	0.978286539	0.021713461	100.0000%

3.4. Conclusion Analysis

From the system of indicators, we can find some characteristics.

The indicators in the demand factor are more evenly affected, with investment demand accounting for the largest share. The study by Qiao Haishu (2006) [15] shows that China's economic growth has developed a dependence on a high investment rate and that investment is the Granger cause of inflation. First, there is a government-driven investment development model in China. With rapid urbanization, a large number of urban infrastructure and transportation facilities have been put into operation, and people's demand for real estate has expanded significantly, causing a continuous expansion of investment demand. Secondly, at the same time, China has relaxed the threshold of foreign investment access after it accedes to the WTO, which has attracted international capital to enter. Finally, investment demand itself has the property of money creation (Zhang Hongbo et al., 2022) [16], and since China's financial system is still underdeveloped compared to developed capitalist countries, the financing system is dominated by indirect financing represented by banks, which constitutes the basis for the creation of large amounts of M2 in China, and according to the Fisher equation MV = PT, it obviously causes an increase in commodity prices.

Among the financial factors, M2 and real estate investment, which account for more than half of the total, can be regarded as direct manifestations of the government's monetary policy, while SHIBOR and real interest rates are indirect manifestations. The former has a direct effect on money demand and supply, and is time-sensitive and highly transmissive, so its high share is reasonable. For example, the central bank can purchase or sell bonds through the open market to control the quantity of money instantly. The latter, on the other hand, requires a certain time lag, such as adjusting the benchmark interest rate takes some time to affect commercial banking, thus transmitting the policy effect to the money market, and is an indirect channel to influence the quantity of money through demonstration and transmission of policy

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signals.

4. Empirical Analysis Based on the VAR Model

4.1. Description of the VAR Model

Traditional econometric methods are based on economic theory to describe models of variable relationships. However, economic theory is usually not sufficient to provide a rigorous account of the dynamics between variables, and the fact that endogenous variables can appear at both the left and right ends of the equation makes estimation and inference more complicated. The vector autoregression (VAR) model, proposed by Christopher Sims in 1980, is an unstructured multi-equation model based on the statistical nature of the data and uses each of the endogenous variables in the system as a function of their lagged values to construct the model. This extends the univariate autoregressive model to a "vector" autoregressive model consisting of multiple time series variables. This can be expressed as follows.

$$\boldsymbol{y_t = \Gamma_0 + \Gamma_1 y_{t-1} + \cdots + \Gamma_p y_{t-p} + \varepsilon_t} \quad (7)$$

In Eq., $\boldsymbol{\Gamma}$ is the coefficient matrix, p is the lag order, and $\varepsilon_t$is the random perturbation term.

4.2. Sequence Stability Test

To prevent the existence of pseudo-regression in regression analysis, a stability test is required for each series of data when the model fitting is performed. In this study, the extended Dickey-Fuller (ADF) test is used to test the stableness of each series.

Table 3: ADF test results.

Variables	t-value	p-value	5% Threshold	Conclusion
Demand factors	-2.230	0.196	-2.878	Unstable
Demand factors (2)	-8.898	0.000	-2.878	Stable
Cost factors	-2.34	0.159	-2.877	Unstable
Cost factors (1)	-5.673	0.000	-2.877	Stable
Structural factors	-0.945	0.773	-2.877	Unstable
Structural factors (1)	-5.399	0.000	-2.877	Stable
Financial factors	-2.627	0.088	-3.469	Stable
Expected factors	-3.016	0.033	-3.467	Stable
CPI	0.802	0.992	-3.468	Unstable
CPI (1)	-2.826	0.055	-3.468	Stable

Note: F (n) denotes the n^{th} order difference of F.

As presented in Table 3, the results of the ADF test confirm that both financial factors and expected factors have p values less than 0.01, indicating a rejection of the null hypothesis with over 99% certainty, hence confirming the time series stability at this point. However, for cost factors, structural factors, and CPI, the corresponding p values are greater than 0.1, indicating that the original hypothesis cannot be rejected, and the series is not stable. To address this issue, a first-order difference is applied to these series, resulting in a stable series. Similarly, for demand factors, a second-order differencing is required to achieve time series stability.

4.3. Determine the Optimal Lag Order

From Table 4, we can see that the AIC criterion should be based on the 13th order, the BIC criterion should be based on the 2nd order, the FPE criterion should be based on the 13th order, and the HQIC criterion should be based on the 2nd order. The smallest of the four indicator values is of order 2, thus the VAR model is finally constructed at lag order 2 in this paper.

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Table 4: Optimal lag order.

Order	AIC	BIC	FPE	HQIC
0	47.942	48.050	662287745568.00	47.986
1	23.542	24.299	16765509154.522	23.849
2	22.352	23.757*	5107325483.473	22.922*
3	22.162	24.215	4235257259.692	22.995
4	22.096	24.798	3991893996.774	23.192
5	21.994	25.344	3642056240.395	23.353
6	21.865	25.864	3253939731.374	23.487
7	21.980	26.628	3734932914.965	23.866
8	21.572	26.868	2559060907.099	23.720
9	21.637	27.582	2839324946.831	24.048
10	21.642	28.235	2998385725.874	24.316
11	21.105	28.347	1866428018.708	24.042
12	20.784	28.675	1462497697.067	23.985
13	19.593*	28.132	487982756.380*	23.056
14	19.609	28.796	555618623.824	23.335
Note: * represents the number of steps under the item.				

4.4. Johansen Co-integration Test

Johansen cointegration tests are performed to ensure that there is a relatively stable equilibrium relationship among the series. The optimal lag order of the VAR model minus 1 is taken as the lag order of the Johansen cointegration test. The results are shown in Table 5.

Table 5: Johansen co-integration test (trace).

Original hypothesis	eigenvalue	Trace	10% Threshold	5% Threshold	1% Threshold
None	0.496	225.032	91.109	95.754	104.964
Maximum 1	0.225	96.066	65.820	69.819	77.820
Maximum 2	0.124	48.166	44.493	47.855	54.681
Maximum 3	0.071	23.375	27.067	29.796	35.463
Maximum 4	0.042	9.443	13.429	15.494	19.935
Maximum 5	0.007	1.305	2.705	3.841	6.635

For the hypothesis ' There are up to 3 covariates in the model ': the value of its trace statistic is 23.375, whose absolute values are all lower than the absolute value of each critical value, implying acceptance of the hypothesis. The same result was obtained for the maximum eigenvalue test. In summary, there is a cointegration relationship in the series and there is a long-term relatively stable trend, and the VAR model can be constructed.

4.5. AR Root Test

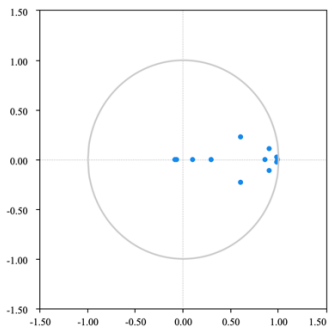

Figure 1: AR Root Test.

The autoregressive (AR) characteristic root test is used to determine the stability of the VAR model.

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If all the characteristic roots of the model fall in the unit circle of radius 1, then the model is stable; if the roots of the model fall outside the unit circle, then the model is unstable and there may be other invalid estimates. Figure 1 shows that all eigen root values are within the unit circle, implying that the constructed VAR model is stable.

4.6. Impulse Response

The results of the impulse response are shown in Figure 2.

It can be seen that 1 standard deviation unit of cost factors has a positive shock effect on CPI in the first 2 periods, and in the 3rd period, the shock effect reaches its minimum, then it starts to rise slowly and stays low in general, and then the shock gradually tends to zero. For example, the impact of cost factors on inflation peaked before the outbreak of the subprime mortgage crisis. 2007 international oil prices rose by 80.29%, and oil, as a basic energy source, would push up the cost of the entire chain from several perspectives, such as industrial products, logistics costs, and raw materials, leading to price increases, however, at a very slow pace.

In contrast to cost factors, the effect of financial factors on inflation is more rapid. The impact of financial factors declines from period 1 to period 2, then rises rapidly to a higher level and then continues to decline. This means that the stimulus was followed by a short-lived reduction in demand, which was quickly followed by demand-driven inflation and financial-factor inflation. The trend is similar to that of demand factors and both of them can be analyzed together. After the subprime crisis, for example, there was a run on the banking system and a liquidity crisis due to the large number of non-performing loans caused by subprime loans, and the Fed injected funds into the financial system by lowering the reserve requirement ratio, open market operations, and indirect financing, causing a rapid rise in the money supply in the short term. At the same time, the "quantitative easing" policy was introduced to essentially expand consumption and income through large-scale investment, thus boosting demand. The effects of this policy were transmitted to China through several channels.

(1) According to the Mondale-Fleming model, an increase in the supply of dollars based on the free flow of capital leads to a decrease in interest rates and an increase in output, which in turn leads to a depreciation of the dollar. Since the dollar has the properties of a world currency, it is an important component of countries' foreign exchange reserves. This will lead to a depreciation of China's foreign exchange reserves as well.

(2) An increase in the supply of the dollar will increase the demand for imported goods in the U.S. It will also lead to an increase in the prices of commodities in the international market, which will in turn affect the demand for imported goods in the Chinese market and push up the production costs of Chinese enterprises.

(3) The increase in the U.S. money supply will lead to a decrease in U.S. Treasury rates, which will result in capital flowing out of the U.S. and into China where interest rates are relatively higher, thus pushing up inflation. In summary, U.S. inflation is transmitted to the domestic market through demand, monetary channels, and liquidity channels. Similarly, the Chinese government has launched an infrastructure program of 4 trillion RMB to expand domestic demand and maintain imports and exports, and RMB issuance has increased significantly to maintain exchange rate stability.

For the expected factor, it has a positive shock effect in the first 6 periods, peaking in period 3 and then turning negative in period 6, and gradually tending to 0. This indicates that after the policy is introduced, it leads the public to have good expectations in the short term, which in turn leads to consumer behavior. However, in the long run, aggressive monetary policies such as large interest rate cuts can lead to severe inflation and currency depreciation, so public expectations will fall. Similarly, after maintaining an accommodative policy in the long run, the public's anticipation of the monetary authority's policy exists afterward, further weakening the role of the expectations factor.

For the structural factor, a one standard deviation shock has a positive effect on inflation in all five periods, but its effect shrinks rapidly in the first three periods and then gradually slows down. This suggests that the lack of an effective resource allocation mechanism after the introduction of the accommodative monetary policy has led to an imbalance in the allocation of resources across sectors, with some sectors having excess production capacity while others, such as agriculture, energy, and transportation, are lagging behind, forming "bottlenecks" in development. When the prices of these "bottleneck" sectors rise due to oversupply, it causes a chain reaction in other sectors, even in the overproduction sector, resulting in round after round of price increases.

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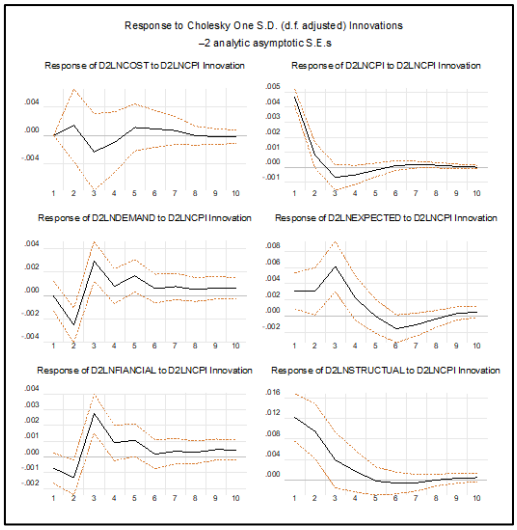

Figure 2: Impulse Response.

4.7. Variance Decomposition

The variance decomposition is an analysis of the contribution of the independent variables to the standard deviation, which in turn assesses the significance of various structural shocks. Thus, the variance decomposition provides an explanation of the relative magnitude of the effect of each confounder. As can be seen from Table 6, the strength of CPI's explanation of its own changes decreases as the period increases, while demand factors, expected factors, and financial factors increase significantly, reaching 5.36%, 3.10%, and 3.54%, respectively, in period 10. Cost factors and structural factors, on the other hand, explain less strongly, at around 2%.

These results show that the aggregate demand side has a stronger influence on inflation and the aggregate supply side has a weaker influence. This study argues that this is due to the fact that China has been in a rapid phase of urbanization over the past 20 years, with GDP growth remaining above 5% on average, a large number of jobs being created, and a large amount of international capital entering. Structurally, the industrial structure has been upgraded, the demand hierarchy has been gradually improved, and the quality of demand has been continuously improved. Although China's marginal propensity to consume is relatively low compared to developed capitalist countries, the increasing income of Chinese residents objectively creates a large amount of consumer demand and, as discussed earlier, the important influence of Chinese government investment, the residential sector, and the government sector together drive demand-based inflation.

Table 6: Variance Decomposition.

Period	Cost	CPI	Demand	Expected	Financial	Structural
1	1.963437	98.03656	0.000000	0.000000	0.000000	0.000000
2	2.478556	88.19952	3. 48647	2.261335	2.457690	1.116425
3	2.600238	84.96404	4.477362	2.766822	3.388442	1.803098
4	2.604554	84.44006	4.832465	2.795289	3.336806	1.990825
5	2.629688	84.16029	4.891687	2.828465	3.507943	1.981928
6	2.635562	83.88458	4.943381	2.998115	3.555215	1.983147
7	2.632552	83.74091	5.012535	3.079715	3.557452	1.976834
8	2.628210	83.62614	5.122317	3.084541	3.552186	1.986608
9	2.624347	83.49534	5.247140	3.079998	3.547842	2.005332
10	2.621162	83.37023	5.366529	3.079411	3.544831	2.017871

5. Conclusions and Policy Recommendations

This paper measures the causes of inflation in China in recent years based on the Entropy-Weighting Method and constructs a system of indicators including demand factors, cost factors, structure factors, financial factors, and expectation factors, and analyzes them using the VAR model. The findings show that: (1) demand-side factors contribute more to inflation than supply-side, and structural inflation and

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cost-push inflation are relatively insignificant. (2) Financial factors are important factors driving inflation, and their response time lags are similar to those of demand factors. (3) Expansionary monetary policy will first hit the market in the short run, and then will strongly promote demand expansion and recovery, but in the long run, will reduce aggregate demand.

In summary, this study gives the following policy recommendations: (1) Pay attention to aggregate demand management, especially to the demand for funds in the financial market, and properly direct the flow of funds to prevent price inflation. (2) Use expansionary monetary policy cautiously and pay close attention to the money supply to prevent hyperinflation. (3) Structural inflation should not be ignored, and food prices should be maintained as stable as possible. (4) Improve the energy structure, strengthen energy self-sufficiency, and try to avoid the impact caused by international energy fluctuations. (5) Improve the exchange rate system and foreign exchange management system, and beware of imported inflation

Admittedly, this paper still has some shortcomings. Compiling several economic variables into a composite indicator certainly allows for a more systematic assessment, but it loses some of the signals of the economic variables.

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