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Game Analysis on the effect of consumer coupons and its impact on CPI

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ABSTRACT

According to economic theory and common sense, the issuance of consumption coupons on one hand stimulated the increasing of residents' consumption, but on the other pushed up the price level. In this paper, using the theory of mechanism design, the game model was built to analyze the relationship between the effect of consumer coupons during the epidemic and the number of merchants participated. The results show that the smaller the merchants' number, the weaker the coupons' effect, vice versa. Then, using KNN regression method, combined with the monthly year-on-year data of CPI from 1998 to 2020, this paper analyzes the changes of CPI forecast value and actual value in the first 10 months of 2020, finding that the actual value of CPI is higher than the predicted one during the first two months of 2020, but lower from March 2020 on, which further verifies the conclusion of game analysis.

KEYWORDS

COVID-19; Consumer coupon; CPI; Mechanism design; KNN regression

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1. Introduction

Corona virus pneumonia outbroke in early 2020 had gave China's economy a big hit, causing a relatively poor performance comparing recent years, with the year-on-year growth rate of GDP in the first 3 quarters of -6.8%, 3.2% and 4.9%, respectively. How to promote a sustainable economic development as soon as possible is the key issue for governments of all countries after the epidemic situation began. China has the largest consumer group in the world, and the consumption market has enormous potential, under this background, China has experienced a long-term rapid economic growth which benefits mostly from the effect of domestic residents' final consumption. The contribution rate of residents' final consumption to GDP is shown in Figure 1 (data from China Statistical Yearbook).

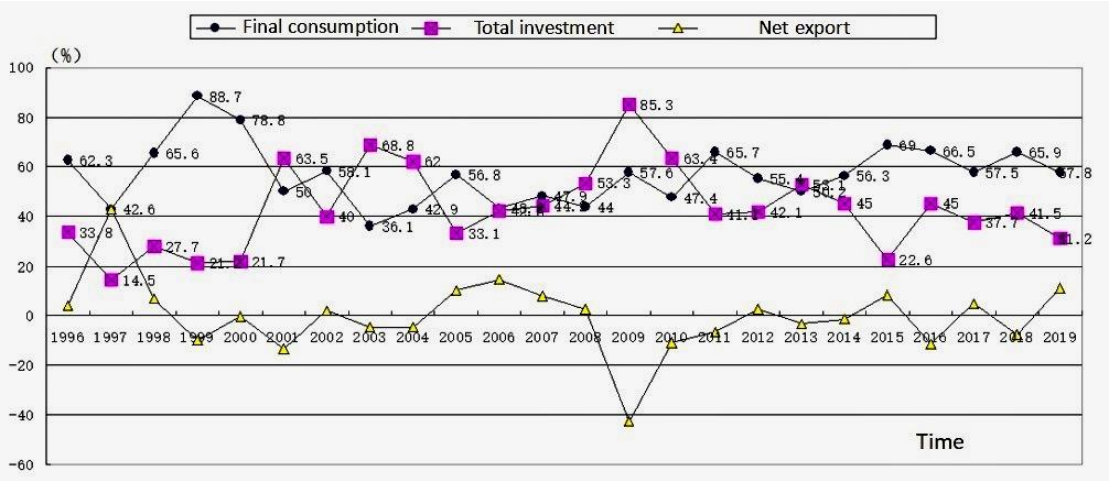

Figure 1. Comparison of contribution rate of residents' final consumption, input-output and export to GDP.

It can be seen from Figure 1 that the most important reason for China's economic growth from 1996 to 2019 is the contribution of residents' final consumption and gross capital formation to GDP, while the contribution rate of net exports of goods and services to GDP is the smallest. For example, in 1999, the contribution rate of residents' final consumption to GDP reached 88.7%, and in 2009, the contribution rate of gross capital formation to GDP reached 85.3%. Before 2013, the contribution of final consumption and gross capital formation to GDP showed a cross state, but since 2013, the contribution of these three factors to China's GDP presents an orderly arrangement, that is, the contribution of residents' final consumption to GDP ranking first, followed by total capital formation, and finally the contribution of net exports of goods and services to GDP. It can be seen that in order to ensure the long-term sustainable and stable growth of China's economy, an important issue that China must always pay attention to is to continuously improve the consumption level and ability of residents.

At the same time, the world economy is also deeply affected by the epidemic, showing a serious downward trend. For example, the GDP growth rates of the United States in the first two quarters of 2020 are 0.32%, - 9.03%, respectively; those of Japan are - 1.93%, - 10.06%, respectively; the growth rates of German GDP in the first two quarters of 2020 are - 2.23%, - 11.26%.[1] As a matter of fact, by the third quarter of 2020, except for China's economic recovery which is reflected by a growth due to a well control of the epidemic situation, the data of the rest of the world's major economies have all show a fallen. China's external economic environment is facing a lot of uncertainties due to the depression of the world economy. Although commodity export plays an important role in and is an important force to China's economic growth, it also causes envy of other countries to often use various anti-dumping measures to restrain China's commodity export to achieve the purpose of protecting domestic enterprises, which makes trade protectionism prevail. In such an external environment, China's goods and services

[1] The data are from the OECD website: www.oecd.com.

export are facing many difficulties, so it is not realistic to rely on commodity exports to drive economic development.

Obviously, in the face of the plight of the domestic and international economic environment caused by the sudden epidemic and considering the huge domestic consumer groups and consumer market, China has adopted the "dual cycle" policy of stimulating domestic consumption, giving priority to internal circulation and supplemented by external circulation, so as to promote sustainable economic development. At present, the issuance of consumption coupons is the main way that local governments have adopted to stimulate residents' consumption growth.

However, while the consumption coupons stimulating the consumption of residents, some people not only question the effect of it but also think that it has pushed up the price of consumer goods and damaged consumer's rights and interests. This paper intends to study the effect of issuing consumer coupons, especially the impact on the prices of consumer goods.

2. Literature Review

Generally speaking, there are two views on the effect of consumer Coupons: one focuses on the positive side. These documents agree that the issuance of consumption coupons by central and local governments plays a positive role in expanding residents' consumption through multiplier effect, which can stimulate consumers' potential consumption desire in a short period of time, drive the consumption amount several times more than that of consumption coupons, so as to promote a growth in the scale of related commodities' industrial chain and a growth of economy(Ahmad , 2011; Greene et al. 2012). For example, Lin Yi-fu and Shen Yan (2020) has analyzed different channels of issuing consumption coupons and found that consumption coupons can significantly lead to the growth of residents' consumption, and have an obvious effect on stimulating residents' short-term consumption. Shi Wen-jun (2010), through sampling data analysis, found that the multiplier effect of the first batch of consumer coupons in Hangzhou is 2.06 times in the hypermarket environment, and about 1.3 times in the supermarket environment. Some western scholars also believe that every 1 trillion consumption coupons can stimulate the growth of effective demand by about 3.5%. If the time limit is shorter, the multiplier effect will be about 4 times (Xue Jing, Mao cheng-lian, 2010).

The second view questioned the effect of issuing consumer coupons. The literature holds that short-term or one-off consumption coupons can not change resident's long-term expectation on income, so is unlikely to change residents' consumption habits(Kietzman, 2016; Laragy et al. 2015; Ruggiano, 2012). Moreover, consumption coupons are often used on the end commodities of the circulation chain, and there are time and space limitations, so it is difficult to promote residents' induced consumption. Wang Cheng (2020) believes that because the fund of consumption coupons was not planed in the financial budget, so to issue it, the use of other funds will be squeezed out. Zhao ping (2020) believes that there are many problems in the process of issuing consumer coupons, such as the supervision of funds, the way of issuing, the objects of issuing and the scope of use, so it's difficult for consumption coupons to play their due effect. At the same time, Liu Si-wei (2020) thinks that although the issuance of consumption coupons can compensate consumption in a short period of time, it will cause many social problems such as unfairness and irrationality, affecting the image and reputation of the government.

Generally speaking, the issuance of consumption coupons has a certain effect on stimulating the short-term increase of residents' consumption, but there are also more problems. At present, the research on the impact of consumer coupons on the prices of consumer goods is still blank. Therefore, this paper analyzes the effects of consumption coupons and the impact of consumption coupons on consumer commodity prices during the epidemic period by constructing game analysis model and statistical regression method to objectively evaluate the impact of consumption coupons on CPI?

The marginal contribution of this paper may lie in: (1) the game model is established for the first time to

analyze the relationship between the number of participants and the effect of coupons; (2) instead of using the traditional time series analysis method, the nearest neighbor (KNN) regression method is used to predict CPI to verify the impact of the number of consumers on CPI.

The structure of the rest of this paper is as follows: the third part analyzes the possible situation of the number of merchants participating in the use of consumer coupons and the effect of consumption coupons under these situations; the fourth part uses the nearest neighbor regression method to predict the CPI value in the first 10 months of 2020, and compares it with the actual value; the fifth part is the conclusion and suggestions of this paper.

3. The number of participating businesses and the effect of consumption coupons

3.1. Participants and tactics

Around the issue and use of consumer coupons, the participants include government (G), retailers (R) and consumers (C).

3.1.1. The government (G)

In the face of the sudden epidemic, the main purpose of the government issuing consumption coupons is to stimulate the growth of residents' consumption and promote sustained economic growth. One of the strategies is to select a scientific method to issue consumer coupons, to play a qualified role in economic supervision, to maximize the effect of consumer coupons and social interests; the second strategy is to fail to choose the right way of issuing consumer coupons, to poorly supervise the use of consumer coupons by retailers, pushing up the price of consumer goods, damaging consumer rights and interests of residents, and as a result the efficiency of consumption coupons is weakened.

In this game of interest, when facing many agents, the principal seems weak and isolated, however, the principal also has adequate initiative. The principal must obtain enough income from the agent to compensate for the cost of the coupon, which is the primary thing the principal need to consider choosing the retailer and issue the coupon.

Therefore, from the perspective of mechanism design, the government, as the principal, should meet the equation (1), as the budget balance conditions:

$$\sum_{i=1}^{n} t_i(\theta) \geq C_0\big(X(\theta)\big), for\ all\ \theta \tag{1}$$

Then, the principal chooses$X(.)$, $t(.)$ to maximize its expected utility under the conditions of participation constraint or what was called individual rationality (IR) and incentive constraint (IC), as the equation (2).

$$\max_{\{X(.),t(.)\}} E_\theta\, U_0(X(\theta), t(\theta), \theta) \tag{2}$$

Among equation (2), $t(\theta)$ is the transfer income from the agent to the principal; θ is the type of agents, which is private information; $X(\theta)$ is the agent's behavior strategy, which is often reflected by the purchase quantity; $C_0(X)$ is the principal's cost, that is, the expected total consumption results from the issuing the consumption coupons; $U(X(\theta), t(\theta), \theta)$ is the principal's utility; n is the number of agents.

3.1.2. Retailers (R)

As the main agent of issuing consumption coupons, retailers aim to make profits, to maximize sales and increase profits by taking advantage of the opportunity of issuing government consumption coupons. In the mechanism design, its involvement restriction (equation (3)) and incentive constraint (equation (4)) are undoubtedly the clearest.

$$for\ all\ \theta, U_1(X(\theta), t(\theta), \theta) \geq \underline{U} \geq 0 \quad (3)$$

$$for\ all(\theta, \hat{\theta}), u_1(x(\theta), t(\theta), \theta) \geq u_1(x(\hat{\theta}), t(\hat{\theta}), \theta) \quad (4)$$

Among them, $\underline{U}$ is the reservation utility of the $\hat{\theta}$ type agent, which is the utility of the agent's nonparticipation and use of the coupon.

3.1.3. Consumer (C)

Consumers are the decisive factor in determining the growth of China's consumption, so the ultimate purpose of issuing consumption coupons is to stimulate residents' consumption intention and as a result, increase consumption. Consumer's involvement restriction (IR) is to bring consumers consumption surplus and to increase consumption intention and probability through the use of consumption coupon; incentive constraint (IC) is to encourage consumers to increase consumption intention and obtain more consumption surplus.

3.2. The number of business participants and the effect of consumption coupons

In fact, in the process of issuing consumer coupons, there are many factors that determine the effect of consumer coupons, such as the way of issuance, the scope of distribution, the amount of money, etc. among them, the number of retailers involved is the key factor in determining the effect of consumption coupons (to stimulate residents' consumption to the maximum extent, that is, to maximize the multiplier effect). In this paper, the possible situation of retailer's participation and the effect of consumption coupon are used to build corresponding models for game analysis. According to the number of retailers involved, the possible game types are as follows:

3.2.1. The effect of consumer coupons when the number of retailers participating is very small

When the number of retailers involved is small, the principal's regulatory role is weakened, and the agent is prone to form a monopoly situation, secretly pushing up the price of products, harming the rights and interests of consumers.

The internal mechanism of agent pushing up the price is as follows: When there are few agents, it is easy for them to form a monopolistic situation and obtain all or even more income than the consumption coupon actually has by pushing up the commodity price. For example, if the original price of a commodity is 50 yuan, and one of the conditions for the use of the consumption coupon is a 10 yuan discount when the price meets 50 yuan then the consumer can obtain the commodity by only paying 40 yuan, in this situation, the consumer has obtained all the income of the consumption coupon. However, when the price of the commodity is adjusted to 50-60 yuan, the merchant and the consumer share the coupon income; when the merchant increases the price of the commodity to more than 60 yuan, the merchant not only monopolizes the coupon income, but also partially damages the interests of the consumer. The latter two cases show that retailers not only enjoy the benefit of coupons alone, but also directly push up the price level. At this time, consumers show no increasing willingness to consume goods by using consumption coupons. Therefore, this paper proposes the following hypotheses:

Hypothesis: When the increase of commodity price exceeds the value of consumption coupons, there will be not increasement in the probability of consumers making transactions, while that of merchants does not decrease.

In this case, we can consider an extreme case when there are only two agents. The agent (seller, commodity provider) provides a unit of goods, and the seller's supply costCobeys distribution $P_1(.)$ on the continuous interval $[\underline{c}, \overline{c}]$; the corresponding density function $P_1(.)$ is obviously differentiable and strictly positive. In this way, for the buyer with unit demand, its value v follows the distribution $P_2(.)$ of continuous interval $[\underline{\theta}, \overline{\theta}]$, and the corresponding density function $P_2(.)$ is differentiable and strictly positive. Now, make $X(c, v) \in [0,1]$ represents the probability of the transaction, and $t(c, v)$ represents the income transferred by the consumer to the agent.

Obviously, it is necessary to discuss whether the effect of consumption coupon is consistent with individual

rationality, incentive constraint and budget balance under this condition.

Order

$$X_1(c) = E_v[x(c,v)] \; and \; X_2(v) = E_c[X(c,v)] \tag{5}$$

The equation(5) represents the possibility of transaction of seller and the buyer respectively.

Order

$$T_1(c) = E_v[t(c,v)] \; and \; T_2(c) = -E_c[t(c,v)] \tag{6}$$

The equation(6) represents their expected transfer earnings respectively.

Order

$$U_1(c) = T_1(c) - cX_1(c) \; and \; U_2(v) = vX_2(c) + T_2(v) \tag{7}$$

The equation(7) represents the expected utility of the seller of type c and the buyer of type v respectively. If the seller monopolizes the consumption coupon and raises the price level, then take the assumed condition of the research into account, the incentive and constraint conditions are as follows: X_1 and X_2 will be monotonous, while X_1 not decreasing and X_2 not increasing. Then:

$$U_1(c) = U_1(\bar{c}) + \int_c^{\bar{c}} X_1(\gamma)d\gamma \; and \; U_2(v) = U_2(\underline{v}) + \int_{\underline{v}}^{v} X_2(v)dv \tag{8}$$

Substituting the above defined expressions of equation(7) and equation(8) into the above expressions and adding them together, we get equation(9):

$$T_1(c) + T_2(v) = cX_1(c) - vX_2(v) + U_1(\bar{c}) + U_2(\underline{v}) + \int_c^{\bar{c}} X_1(\gamma)d\gamma + \int_{\underline{v}}^{v} X_2(v)dv \tag{9}$$

Budget balance $(t_1(c,v) + t_2(c,v) = 0)$ means

$$E_c T_1(c) + E_v T_2(v) = 0 \tag{10}$$

Or, by the equation(11)

$$\int_{\underline{c}}^{\bar{c}} \left(cX_1(c) + \int_c^{\bar{c}} X_1(\gamma)d\gamma \right) p_1(c)dc + U_1(\bar{c}) + \int_{\underline{v}}^{\bar{v}} \left(\int_{\underline{v}}^{v} X_2(v)dv - vX_2(v) \right) p_2(v)dv + U_2(\underline{v}) = 0 \tag{11}$$

Partial integration of the equation, we get equation(12):

$$U_1(\bar{c}) + U_2(\underline{v}) = -\int_{\underline{c}}^{\bar{c}} \left(c + \frac{1-p_1(c)}{p_1(c)} \right) X_1(c)p_1(c)dc + \int_{\underline{v}}^{\bar{v}} \left(v - \frac{1-p_2(v)}{p_2(v)} \right) X_2(v)p_2(v)dv \tag{12}$$

Substituting the definitions of X_1 and X_2 into the equation(12), we get equation(13):

$$U_1(\bar{c}) + U_2(\underline{v}) = \int_c^{\bar{c}} \int_{\underline{v}}^{\bar{v}} \left[\left(v - \frac{1-p_2(v)}{p_2(v)} \right) - \left(c + \frac{1-p_1(c)}{p_1(c)} \right) \right] x(c,v)p_1(c)p_2(v)dcdv \tag{13}$$

Because the seller and buyer are rational, which can be equivalent to $U_1(\bar{c}) \geq 0$ and $U_2(\underline{v}) \geq 0$, so configuration X(.) can only be implemented when the right side of the above formula is non negative

Considering the effectiveness of the configuration, it is required that $x(.) = x^*(.)$, here $x^*(c,v) = 1$ when v ≥ c, otherwise $x^*(c,v) = 0$. It can be verified that if $\bar{c} > \underline{v}$ and $\bar{c} < \underline{v}$, at the same time, $x(.) = x^*(.)$, then the equation of the above formula is impossible to hold. In this way, we can draw the following conclusion: suppose that the seller's commodity cost and the buyer's value are respectively on $[\underline{c}, \bar{c}]$ and $[\underline{v}, \bar{v}]$, there are strictly positive and differentiable density functions, and the probability of transaction being effective, that is $(\underline{c} < \bar{v})$ or $(\bar{c} > \underline{v})$, is not equal to zero. Then, there is no effective transaction whose result satisfies the budget balance constraint, individual rationality and incentive constraint at the same time.

Conclusion 1: Assumed that the seller's cost and the buyer's value are strictly positive differentiable density functions on $[\underline{c}, \bar{c}]$ and $[\underline{v}, \bar{v}]$, respectively, and the probabilities of efficient transaction $[\underline{c}, \bar{v}]$ and $[\bar{c}, \underline{v}]$ are nonzero. There is no effective transaction that satisfies participation constraint, incentive constraint and budget balance at the same time.

3.2.2. The effect of coupons when a large number of retailers participate fully

If we fully guarantee that all retailers fully participate in the use of consumer coupons from the institutional arrangement, then consumers can get the maximum expected return by participating in the use of consumer coupons, which is consistent with the original intention of the government to issue it. Of course, it meets the consumers' participation constraints and incentive constraints.

If the consumers and retailers have incomplete information about each other and the probability of invalid transaction is not zero, then both sides of the transaction cannot obtain all the benefits in the use of the coupon. However, under the condition of a large number of retailers and consumers, that is to say, it is impossible for any party in the transaction to influence its own trading conditions with its own actions, in this case, the optimal allocation transaction similar to Pareto can be implemented.

It is assumed that the types of both sides of the coupon are subject to continuous distribution, and each seller has a unit of goods for sale, the opportunity cost of goods which is represented by c (cost value independent of other retailers) is derived from distribution p_1 on continuous interval $[\underline{c}, \bar{c}]$. Similarly, it is assumed that the consumers in the transaction also have the unit demand v, whose value is taken from the independent distribution $p_2$on the continuous interval $[\underline{v}, \bar{v}]$. In this way, if$\bar{c} > \underline{v}$, then the clearing price π is determined by $p_1(\pi) = 1 - p_2(\pi)$. Now, make $x_1 \in [0,1]$ and $x_2 \in [0,1]$ represent the probability of the seller selling and the buyer buying respectively. Then, the market can provide two parts of the transaction with the below mechanism, to achieve the effective outcome: "If $\hat{c} \leq \pi$, then $x_1(\hat{c}) = 1$and $t_1(\hat{c}) = \pi$, otherwise $x_1(\hat{c}) = t_1(\hat{c}) = 0$; if $\hat{v} \geq \pi$, then $x_2(\hat{v}) = 1$ and $t_2(\hat{v}) = -\pi$, otherwise $x_2(\hat{v}) = t_2(\hat{v}) = 0$".

Conclusion 2: if there are many retailers and many coupons were used, Pareto optimal allocation can be implemented even under asymmetric information.

3.2.3. The effect of consumption coupon with limited retailer participation

Assume that the retailer and the consumer who use the coupon will negotiate whether to participate in the coupon transaction and at what price. Obviously, as long as the time preference of both parties is the same, the game can also be carried out. In this case, we may consider the case that there is only a single retailer and a consumer. Suppose that the bargaining game between the two sides about how to use the consumer coupons starts from period 0, and regarding the time value, both sides of the transaction use the market interest rate $r > 0$ as their discount factor to discount the income value of each stage in the future. Assumed a buyer whose value is v and the seller of the goods whose cost is chas reached a sale and purchase agreement at time $\tau(c, v)$ and concluded the transaction at the price Z(c, v), $\tau \to \infty$ on the other hand means that the buyer and the seller have not reached an agreement. Then it is defined as the equation(14):

$$\begin{gathered} x(c,v) = e^{-\gamma\tau(c,v)} \in [0,1], \qquad w(c,v) = e^{-\gamma\tau(c,v)} z(c,v) \\ U_1(c) = E_v[w(c,v) - cx(c,v)], \quad U_2(c) = E_c[vx(c,v) - w(c,v)] \end{gathered} \tag{14}$$

Note: the time $(\tau > 0)$ it takes to reach an agreement here is equal to the probability that the transaction will not occur $(x < 1)$.

Now solve the expected trading gain:

$$\begin{cases} E_{c,v}[(v - x)x(c,v)] \\ s.t. \ E_{c,v}\{[J_2(v) - J_1(c)]x(c,v)\} \geq 0 \end{cases}$$

Here:

$$J_1(c) = c + \frac{1 - p_1(c)}{p_1(c)}, J_2(v) = v - \frac{1 - p_2(v)}{p_2(v)} \tag{15}$$

On the contrary, if x(.) is the solution of

$$\begin{cases} maxE_{c,v}[(v-c)x(c,v)] \\ s.t.\ \ \mathrm{E}_{c,v}\{[J_2(v)-J_1(c)]x(c,v)\} \geq 0 \end{cases}$$

then there is a transfer income function $t(.,.)$ satisfying equation(3), equation(2) and equation(1), if $X_1(c) = E_v x(c,v)$ is not increasing and $X_2(v) = E_c x(c,v)$ is not decreasing. Now, make $u \geq 0$ the Lagrange factor corresponding to the equation, then the Lagrange function formula of the corresponding programming problem is as the equation(16):

$$\Re = \mathrm{E}_{c,v}\big(\{(v-c)+[J_2(v)-J_1(c)]\}x(c,v)\big) \tag{16}$$

The first order conditions are as follows:

$$x(c,V) = \begin{cases} 1, v + uJ_2(v) \geq c + uJ_1(c) \\ 0,\ others \end{cases}$$

In this way, the transaction occurs when and only when satisfying equation(17):

$$v - \left(\frac{u}{1+u}\right)\frac{1-p_2(v)}{p_2(v)} \geq c + \left(\frac{u}{1+u}\right)\frac{1-p_1(c)}{p_1(c)} \tag{17}$$

If the monotone or likelihood rate condition holds, that is, $\left(\frac{P_2}{1-p_2}\right)$ not increasing and $\left(\frac{P_1}{1-p_1}\right)$ not decreasing, we can find $X_1(.)$ and $X_2(.)$ monotone, so it is the optimal trading rule.

Conclusion 3: when the number of both sides of the transaction is limited, the transaction also has certain efficiency through the effective negotiation process.

4. Measurement of the impact of consumer coupons on CPI

4.1. The KNN regression analysis method and its principle

4.1.1. KNN regression analysis

Traditional time series prediction methods often use ARIMA or exponential smoothing method (Robert and Poulos, 2014). However, with the wide application of artificial intelligence technology in recent years, it also shows some unique charm in the field of time series prediction, for example, the artificial neural network is currently very popular, along with Gaussian stochastic process and KNN regression (Robert et al. 2011), all have some unique properties in intelligent computing methods, like in the aspects of nonlinear or non-parametric variable relationship. KNN is a widely used algorithm in classification or regression analysis. It stores some cases (training sets) in advance, and when testing test set cases, it can find cases similar to existing cases for regression analysis or classification, which are very flexible (Fernandez et al. 2018; Moran et al. 2012; Friedman, 1973).

When KNN method is applied to time series prediction, the samples need to be divided into two parts: training set and test set. The training set is used to fit the regression model, and then applied to the test set data to test the model accuracy. In this case, the time series data is the collection of time series values related to the target, and the characteristic of description examples is the lag value of the target. For example, there is a time series of 132 monthly observations over 11 years: T = {X1, X2, X3, X4, X5, X6, X7, X8,⋯,X132}, suppose its next month's data is needed. Because only one value is predicted, the goal of the training instance is to use the first 12 lag values in the time series to predict the new instance which is the next future value in the time series. Because the data of lag periods 1 to 12 are used as feature vector, so the feature vectors associated with the next future point are vectors (X121, X122,⋯,X132). It is composed of the last 12 values of the time series, for example, if k equals 2, then the two nearest neighbors of the new instance will be found, and their goals are aggregated to predict the next month.

4.1.2. The basic principles of KNN for time series prediction are as follows

Time series can contain repetitive patterns. It is hoped that in the future time series, their patterns are similar to those in the past time series, and similar patterns were hoped to be seen.

Time series t = {X1, X2, X3, X4, X5, X6, X7, X8,⋯,X132}. The training examples with feature vectors of forward prediction and a lag of 1:12 are shown in the following table:

Table 1. Schematic diagram of KNN forward prediction principle.

Eigenvalue	target value
X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12	X13
X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12, X13	X14
X3, X4, X5, X6, X7, X8, X9, X10, X11, X12, X13, X14	X15
... ...	
X120, X121, X122, X123, X124, X125, X126, X127, X128, X129, X130, X131	X132

The principle and method of forward prediction described here is the same as that of multi-step forward prediction, while there exists many multi-step forward prediction methods, such as MIMO (multiple input multiple output, MIMO), and recursive method.

4.2. Empirical analysis of KNN

4.2.1. KNN prediction

This paper selects CPI monthly year-on-year data from January 1998 to October 2020 in China as the sample data. Due to the main analysis of the impact of 2020 epidemic on CPI, the training set data is up to December 2019, and the 10 monthly CPI data in 2020 are taken as the test set. In this paper, the tsfknn package of R software is used for KNN (K Nearest Neighbor, KNN)regression analysis (k = 2, i.e. to find the two nearest neighbor cases for prediction analysis, and the predicted value is the average value of the two nearest neighbor values), and the multi-step forward prediction method is used for prediction analysis. The software running results are as follows.

Table 2. KNN forecast value of CPI in the first 10 months of 2020. unit:%

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
actual value	5.38	5.17	4.27	3.29	2.44	2.48	2.70	2.38	1.70	0.50
Recursive prediction	4.525	4.745	4.900	5.150	5.350	5.400	5.950	6.450	6.350	6.150
MIMO prediction	4.855	4.745	4.900	5.150	5.350	5.400	5.950	6.450	6.350	6.150

It can be seen from table 2 that The actual CPI values from January to February 2020 are 5.38% and 5.17% respectively, while the recursive prediction values of KNN are 4.525% and 4.745% respectively, and the MIMO prediction values are 4.855% and 4.745% respectively, which shows that the actual value is higher than the predicted one, while the actual value from March to October was lower than the predicted one. It can be seen that in the process of nationwide closure of the city in early 2020, because only a few supermarkets was operating, compared with the previous seasonal price changes, the price rise this time was "a little high". Due to the fact that only a few large supermarkets operated at that time, and the government had set a high threshold for entry when consumer coupons was first used, which requires businesses to participate in registration, application, examination and other procedures, at the same time, many retailers didn't participate in the use of coupons in the early stage because of the shortage of information, a small number of retailers formed a relatively monopoly position, which caused commodity prices to rise and helped the retailers obtain the maximum income of consumption coupons, thus directly pushing up CPI.

Since March, with the strict management and control of the epidemic situation in China, the epidemic situation has been basically controlled and gradually eased. At the same time, all walks of life have returned to work and production. Many retail businesses have reopened. In particular, the change in the way of issuing consumer coupons and the expansion of the scope of distribution had made many businesses participate in the use of consumer coupons, completely breaking the situation from January to February that only a few retailers operated, and the prices of residents' living goods and services fell rapidly. It can be seen from table 2 that since March, China's CPI fell rapidly, far below the predicted value.

In order to show the change of CPI and forecast value more vividly, the comparison between them is shown as follows.

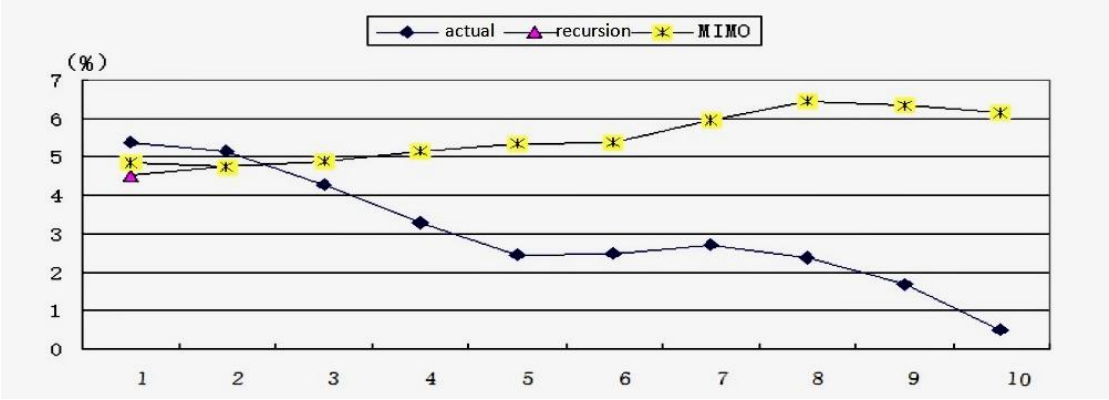

Figure 2. Comparison and analysis of KNN forecast value and actual value of CPI in the first 10 months of 2020.

It can be seen from Figure 2 that the actual value of CPI shows a rapid downward trend, while the predicted value of CPI shows a slight increase under overall stability. At the same time, it is observed that the KNN prediction value, whether the prediction result of recursive method or the prediction result of MIMO, is almost synchronous, with very small difference.

4.2.2. The nearest neighbor graph of KNN prediction value

Now put the CPI prediction value in the whole sample range and observe the comparison between the predicted value and the sample value.

As shown in Figure 3, the CPI forecast value in the first 10 months of 2020 continues the upward trend in 2019. According to the data in Table 2, in the first two months of 2020, the actual CPI is higher than the predicted one because the use of consumer coupons is concentrated in a small number of businesses and has a certain monopoly nature. From an empirical point of view, the above game analysis is verified, that is, the use of consumer coupons concentrated in the hands of a small number of businesses is to reduce the role of consumer coupons and the multiplier effect it bears, push up the price level, and damage the interests of consumers. From the third month of 2020, with the gradual recovery of the resumption of work and production, the number of merchants using consumer coupons is expanding rapidly, the multiplier effect of consumer coupons is gradually emerging, and the prices of consumer goods also begin to fall, lower than the predicted value. It can be seen that the results of empirical analysis and game analysis are consistent, thus playing a role of mutual corroboration.

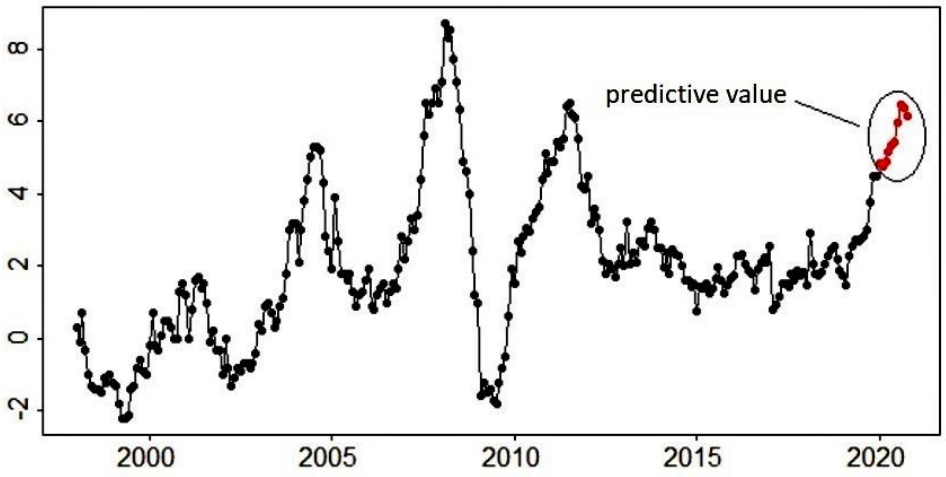

Figure 3. The predictive value of CPI.

Now, two cases (placed in one graph) which are the closest neighbors to the change of CPI after 2020 are shown in Figure 4.

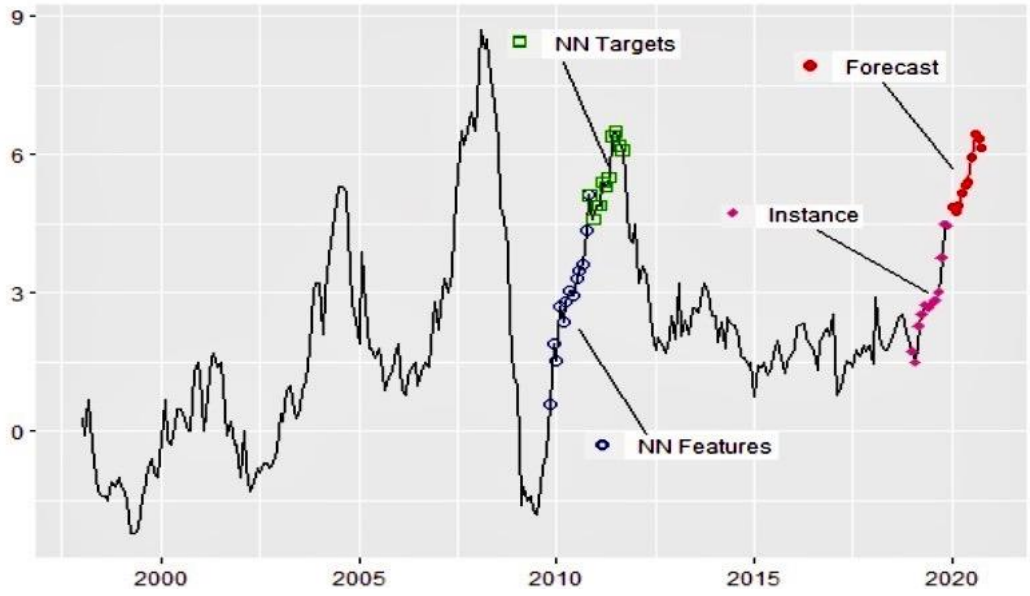

Figure 4. Two sample cases of nearest neighbor.

It can be seen from Figure 4 that the most "similar" situation with the CPI trend in 2020 is the CPI change in 2010 and 2011, the CPI trend in 2019 is similar to that in 2010, and the predicted value (mean value) of 2020 is similar to the trend of CPI in 2011, showing a "nearest" distance.

In terms of time, 2010 and 2011 happened to be the period when the weights of new and old CPI categories were adjusted and updated, leading to some structural mutation characteristics in CPI, and are similar in pattern with the national turbulence caused by the novel corona virus epidemic in early 2020, which made the trend of CPI appear some big, mutagenic phenomena.

5. Conclusion and suggestion

From the above research, we can draw some basic conclusions: Firstly, the number of merchants participating in the use of consumer coupons has an important impact on the effect of consumer coupons. The small number of

participating businesses will easily lead to the formation of a short-term monopoly situation for retailers, which will drive up the prices of commodities and keep the profits of consumer coupons to themselves. When the number of participating merchants is large enough, the effect of consumption coupon is high. Secondly, The result of empirical analysis shows that during the epidemic period, the retailers have managed to raise the prices of commodities because of the temporary monopoly situation of commodity supply, caused by the national closure of cities, which was shown by the higher actual value of CPI than the predicted one, under this situation, the retailers obtained the income of consumption coupons to the maximum extent, which damaged the consumer rights and interests of residents.

According to the study of this paper, the following suggestions are put forward: Firstly, strengthen the supervision of commodity prices before and after the issuance of consumption coupons. Before and after the issuance of consumer coupons, the change of commodity prices should be monitored, and the behavior of maliciously increasing prices and swallowing the proceeds of consumer coupons should be punished; Secondly, the threshold for the use of consumer coupons should be lowered to allow more retailers to participate in the use of consumer coupons. From the above research, we can see that only when the number of retailers participating is enough, even if the information between the buyer and the seller is asymmetric, the effect of the consumption coupon will be good; Thirdly, improve the method of issuing the consumption coupon. At present, the issuance of consumer coupons in many parts of the country is unfair to many elderlies, rural people, and remote residents in the way of only insuring it on the electronic payment platform such as Alipay and WeChat. It is a deep-rooted thought in human society that "do not suffer from oligopoly but suffer from inequality", but the current way of insuring coupons is likely to aggravating social injustice. What’s more, it is not a civilized phenomenon for residents to rush to the payment platform for consumption coupons within a limited time. In fact, there are many mature practices in foreign countries which can be learn from, for example, the practice of the United States, Japan and Macao distributing cash to every resident is worth learning, or China can improve it to the form of distributing consumer coupons.

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Conflict of interest

All authors declare that they have no conflict of interest.

Author contributions

Conceptualization & Methodology & Writing-review & Editing: Xiu-hai Huang; Data & Writing-original draft: Ping Yu; Empirical analysis: Xiu-Hai Huang and Ping Yu.

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