Times Series Analysis on Inflation in the U.S. under COVID-19 Pandemic

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Abstract. The COVID-19 pandemic has affected the economic environment in the U.S, particularly in inflation, which is experiencing its highest levels in decades. The reasons for this high inflation might be change in supply relations and consumer habits, logistics bottlenecks and policy reasons. The Fed has raised interest rates several times in hopes of a quick return to pre-pandemic inflation rate, but it is still in a high level around 0.08. Given the complex international situation, it is obvious that high domestic inflation and prices will significantly drag down GDP and economic growth. However, if reducing the current situation of high inflation in a short period, it is obviously not only by raising interest rates. The correct path is to find the real causes of inflation and solve these. Unfortunately, the exogenous shocks not only frequently affect the stability of price and inflation but fuzz the real reasons behind inflation, which leading to a difficult process of finding the causes.

Keywords: Inflation; CPI; Core-CPI; Time series analysis.

1. Introduction

With the exogenous shocks continuously impacting, the U.S. has been a tough time and suffered a serious inflation. After the three years pandemic, the global economic has significantly changed, especially in international trade, supply chain and consumption end. Those changes irreversibly leaded to non-transitory inflation around countries. As an important economic entity, the U.S. has confronted an even more complex challenges under this situation. In addition, not only the COVID-19 but other exogenous shocks, such as the Russia-Ukraine conflict, also affect its economics. Therefore, this paper researches the U.S. inflation and volatility of price index for effectively revealing the macroeconomics' change effected by pandemic.

The aim of this paper is to analyze indicators of inflation and find the economic implications behind the surfaces which can help policymakers to seek solutions to smooth the inflation, and for business leaders and householders, they can avoid involving in financial risks. The pandemic leads to many countries implement the epidemic prevention and control which causing a widespread restriction in social work in the first year or even until 2022, hence there is a substantial number of blockages in international trade, damages in supply capacity and changes in consumption structures [1]. At present, the fact of inflation in the U.S. has been observed, but the reasons behind the surface are various that many exogenous variables involving in, which has seriously impacted on the employment, the level of outputs and even the policies making. According to the equation of exchange, where M is money supply, V is velocity of circulation, P is price level, and T is transactions.

$$MV = PT \tag{1}$$

The variables in the equation (1) almost change in a short period hence it is complex to search what specific reason rises inflation. During pandemic, the total social income and the needs to different commodities changed and shows some specific trend, therefore analyzing those indicators' performances is possible to find the reasons to inflation. Once understanding the reasons, the corresponding solution can be effectively provided. The factors influence inflation is variable and complex, this paper mainly focuses on using time series to analyze and forecast inflation rate, CPI and Core CPI. The exogenous shocks and pandemic directly affect the price index increasing in a short period. These effects caused many changes, such as changing in consumption patterns, the relationship of supply and demand and obstructions of logistics. Therefore, using time series to

analyze the inflation rate, CPI and Core CPI could be possible to figure out the statistical point of inflation changing and provide the evidence to support how these shocks affected inflation. In addition, the different item's price change leads to impact on different groups, especially exerting impact on the low-income families [2]. The possible tendency of inflation can be forecasted by tools of statistics, and it is the source of basis of recommendations. In this paper, R software is used to establish time series with the monthly data from the U.S. Bureau of Labor Statistics and data collection websites. As focusing on the impact of the pandemic on inflation, the data selected too early is not effectively comparable during pandemic, the data selected is from Jan 2014 to Sep 2022.

This paper is organized as the follow structures. Section II describes the indicators' sources, meaning, visualization and analysis what the relationship and significance with these indicators and why there are some specific statistical values occurred. The possible influences of inflation on macroeconomics and householders are discussed in section III. Section IV forces on forecasting and recommending. The conclusion summarizes the results, finding, suggestions and the might further research direction.

2. Analysis based on the Inflation Indexes

The inflation is generally described as the price of commodities is increased, but not once the price is increased the inflation is because there are many factors draw up the price. The inflation often generated with over supply of currency, the relationship between supply and demand, the policy, and the frequency of stocked commodity circulation. Although the exogenous factors are superposable to affect the inflation, and the degree of influence cannot be effectively quantified, the influence ability can be roughly analyzed by comparing the differences before and after the emergence of external influencing factors. Therefore, this paper analyzes the data characteristics of the inflation rate, CPI, Core CPI before and after the pandemic to figure out the reasons.

As shown in figure 1, the trend of monthly inflation rate (source: Statista Database) is stable around 0 to 0.025 before 2021 [3]. However, begin with the pandemic, its trend has a dramatic increasing until Sep 2022. This is evidence that inflation is with pandemic. Moreover, there was a highlight surge in early 2021 which raised with a significant speed to the peak about 0.09 in Jun 2022. There are considerable values in the Figure 1 after pandemic, such as in Jan 2021 and Jun 2022, as these points are the trend start and the peak in the plot, which has specific meanings. In the Figure 2, the seasonal plot in years shows that from 2014 to 2020 are statable around 0 to 0.025 and have not very clear seasonality, however the year 2021 and 2022 are different from previous with a high level and stand at about 0.8 in 2022.

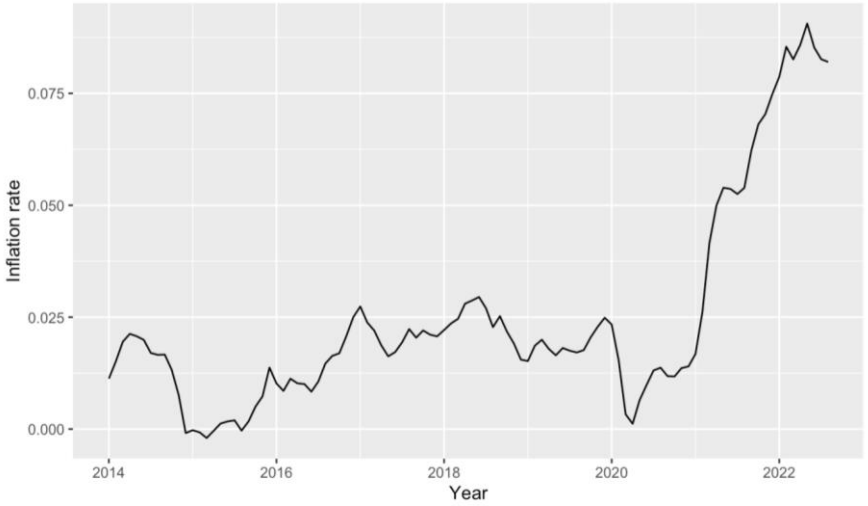

Fig. 1 Monthly inflation rate of U.S. from 2014 to 2022 (Photo credit: Original)

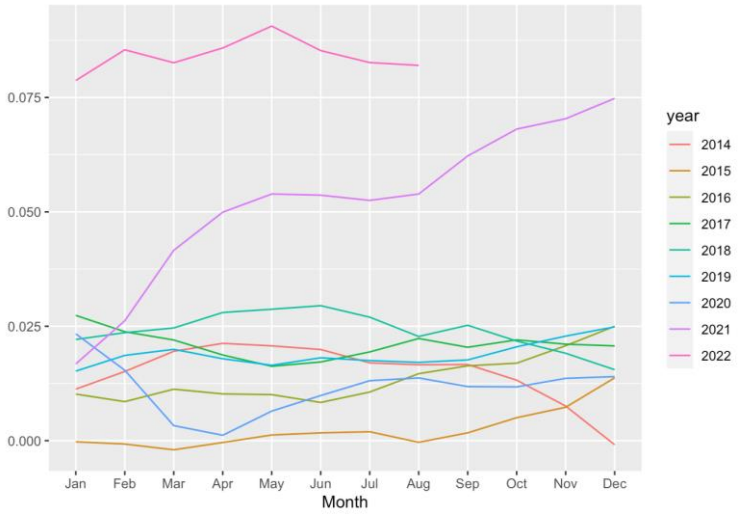

Fig. 2 Separate Monthly inflation rate of U.S.by year from 2014 to 2022 (Photo credit: Original)

The character of inflation which often with time-lag effect causes the above special observation that the inflation starts from 2021 not 2020. The gap between actions and effects results in exploring the reasons may in an early time. This can explain why the 2020, in which the pandemic has been started, still has a similar trend and range with the previous years, and the inflation starts in 2021. Some may argue that the increasing trend in 2021 is caused by the implement of President Biden's 1.9 trillion covid-19 relief law, but it should be note that before the law's effective date May 2021, the inflation rate has begun to dramatically rise [4]. The main reason of the augmentation of inflation rate could be, firstly, due to the quarantine policy, the supply is shortage in 2020 which leads to the aggregate demand is greater than supply, that is, the relative rise in commodity prices and therefore the relative depreciation of the currency. Secondly, the pandemic reduced the efficiency of logistics causing the temporary shortage of goods. For the international trade, this effect is remarkable, especially causing food prices to rise in the early of the pandemic and a wave of international chip shortages, which reduced the value of currencies in relative terms [5]. Thirdly, as the unemployment extremely raised in 2020, the income of householders is decline which causes the marginal propensity to save decreasing and the marginal propensity to consume increasing, that the currency more frequently circulating in the market [6]. Finally, after the pandemic has affected the entity for a year, 1.9 trillion relief law acts as a catalyst accelerating affect the increase in inflation. The latest inflation rate began to decrease from Jun 2022, this is relied on the action of Federal reserve rate hike, the restoration of supply capacity and uncertainty of the market. With the rate hike, the willingness to save increase, reducing the amount of money in the market. In addition, as the death rate from the Omicron virus falling, governments began to gradually restore production and implementation of the economic stimulus package, lead to the shortage of commodities being gradatim smoothed. Moreover, the increase in employment and the restoration of market order have mutually facilitated an increase in aggregate income and marginal savings that leads to less money in the market. Finally, the emotion of uncertainties to future, including the Russia Ukraine conflict and the lower GDP growth forecasts for next year has dampened the investment confidence also reduce the circulation of currency in the market [7]. The combined effects of these factors resulted in the decrease of the amount of money in circulation and the relative decline of the prices, which fought against inflation.

Comparatively analyzing CPI and Core CPI (source: Bureau of Labor Statistics) can provide the patterns of commodity price movements during the pandemic and the fluctuations of different commodities, especially energy and food, which are considerably affected by exogenous factors [8]. In this paper, food and energy are excluded from the calculation of Core CPI. It can be seen from Figure 3 and 4 that CPI and Core CPI performance different slopes before and after the pandemic with the rise is faster after the pandemic. Figure 5 shows that, before the pandemic, the rate of change basically remained between -1% to 1%. However, after the pandemic, the rate of change was about

1% to 3%, even in early 2022, CPI showed a monthly increase of nearly 4%. Figure 6 shows the seasonal changes of the two indicators are similar from 2020 to 2021, but the Core CPI increases at a slightly slower rate than the CPI and a big gap in early 2022.

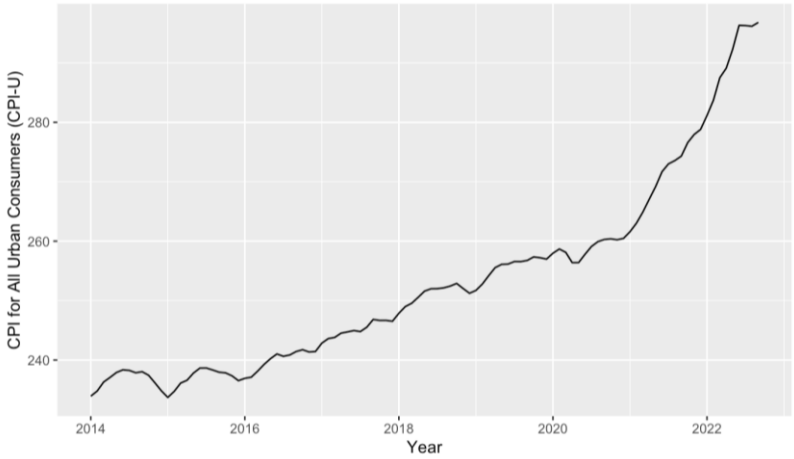

Fig. 3 CPI for all urban consumers from 2014 to 2022 (Photo credit: Original)

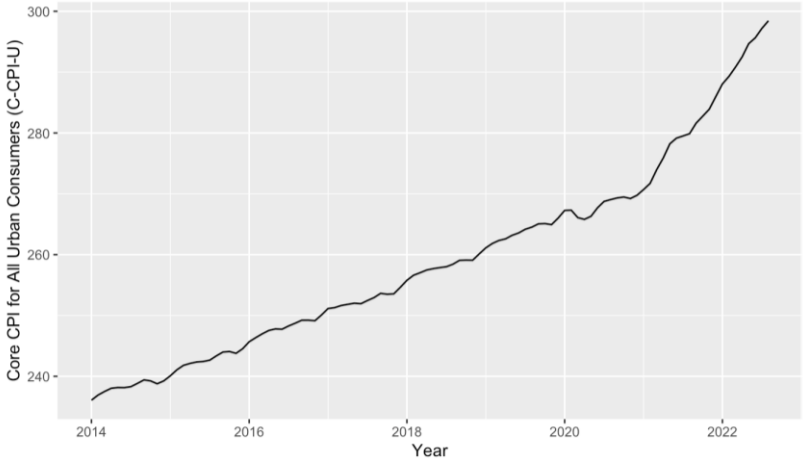

Fig. 4 Core-CPI for all urban consumers from 2014 to 2022 (Photo credit: Original)

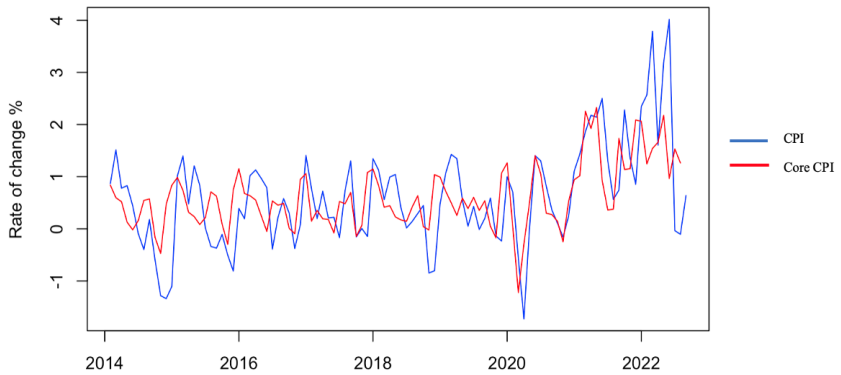

Fig. 5 Change rate of monthly CPI and Core-CPI for all urban consumers from 2014 to 2022 (Photo credit: Original)

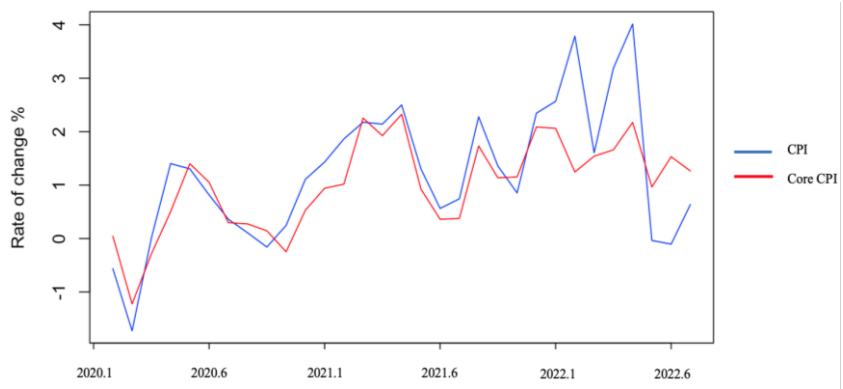

Fig. 6 Change rate of monthly CPI and Core-CPI for all urban consumers from 2020 to 2022 (Photo credit: Original)

The reasons causing CPI and Core-CPI increasing are partly similar as the inflation, which are logistics congestion and capacity reduction, but there are special factors, including a change in consumption habits and challenges of energy shortage. Compared to the inflation rate, those price indexes are more sensitive to the impact of pandemic as shown in the figures, as they have changed significantly since 2020. This is because commodity price is relied on the relationship of supply and demand. With the logistics stocked and factories closed, the shortages of commodities at the beginning of pandemic caused prices quickly rising. In addition, due to the declining income and long-term home life, residents' spending on basic commodities, such as energy and food, has increased. Therefore, the shortage of goods and the excess of demand resulting in the food and energy ‘s prices increasing which leads to the curve of Core-CPI slightly lower than CPI. This impact on low-income families is pronounced because their food expenditure as a proportion of income is already large, and with the impact of rising prices and falling incomes, their food expenditure as a proportion of income would be even larger. The explanation for the gap between CPI and Core-CPI in early 2022 is the rising of energy prices. However, this assumption could not be proved effectively, because although the Russia-Ukraine conflict has affected energy supply, policy-induced high inflation has also caused price increases. Finally, for mid-2022, the decline in CPI growth is may due to the recovery of social and industrial activities and the economic stimulus activities. However, at the same period, Core-CPI has not effectively decreased, the reason may be caused by the characteristics of Core-CPI, that is, it does not count the commodities item easily affected by external factors, hence it is relatively stable. As the analyzing above, under the pandemic, the causes of inflation could be cost-push and policy-push inflation.

The above analysis represents a variety of factors influencing the inflation and price rise in the U.S. after the pandemic, including the policy monetary stimulus, the decline of residents' income and the change of consumption habits, hence the impact of inflation this time could be special. Firstly, for the government, the U.S. faces the coexistence of anti-recession and anti-inflation. In order to resist the economic recession caused by the pandemic, it has to lose price stability to increase the amount of currency, but for restraining the excessive price, it needs to raise interest rates to stabilize the inflation rate. The two sides of conflict are dynamically affecting domestic deposit rates and inflation, which causing the increasing in dollar’s value. On the one hand, the result would attract foreign investment and exchange into the U.S. market, which could help stabilize business confidence. On the other hand, a high dollar price would affect the competitiveness of export industries. Secondly, the increase of government subsidy expenditure leads to an increase in the deficit, which will further aggravate the development of inflation. In addition, the uncertain factors of the Russia-Ukraine conflict, and the reduction of immigration and the shortage of labor force will cause a more complicate process to formulate policies [9]. Secondly, for individuals, although the interest rate hike increases the nominal interest rate, the high inflation rate makes the real interest rate rise slightly. In addition, on further consider of the influence of rising prices may lead to a devaluation risk of personal

assets. For residents, especially low-income families, the rising price, and inflation rate further reduce their real purchasing power, thus reducing the quality of life.

3. Forecasting based on the ARIMA Model

In this paper, based on the above data, the ARIMA model in R software is used to forecast the inflation rate, CPI and Core CPI. In the process of parameter selection, this paper uses the values of AICc, BIC, the Box-Ljung test results, ME, RMSE, MAE, MPE, MAPE and MASE to comprehensively select, and the forecasting results are as follows. In Figure 7, the inflation rate is likely to remain high, and as shown in Table 1, the estimated value is about 0.08. For the CPI, Figure 8 shows that the curve remains on an upward trend, and Table 2 presents the point estimate of CPI is. As Figure 9 shows the projected trend of Core CPI, compared to Figure 8, Core CPI is rising at a slightly larger rate than CPI, with table 3 shows the point estimates of Core CPI.

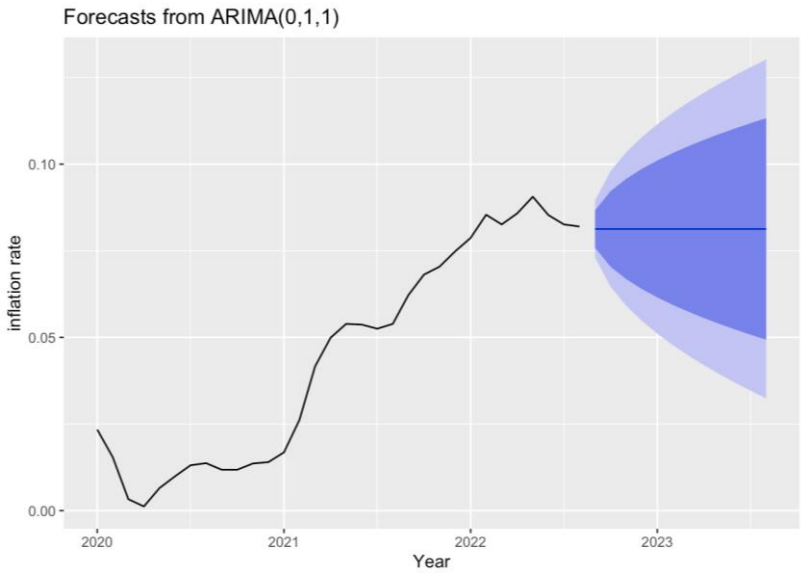

Fig. 7 Monthly inflation forecast plot for 12 lags (Photo credit: Original)

Table 1. Monthly inflation forecast for 12 lags

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Sep 2022	0.08129443	0.07589174	0.08669712	0.07303173	0.08955713
Oct 2022	0.08129443	0.07036294	0.09222592	0.06457615	0.09801271
Nov 2022	0.08129443	0.06680975	0.09577911	0.05914202	0.10344684
Dec 2022	0.08129443	0.06397061	0.09861825	0.05479994	0.10778892
Jan 2022	0.08129443	0.06153530	0.10105356	0.05107545	0.11151341
Feb 2022	0.08129443	0.05936884	0.10322002	0.04776213	0.11482673
Mar 2022	0.08129443	0.05739798	0.10519088	0.04474797	0.11784089
Apr 2022	0.08129443	0.05557773	0.10701113	0.04196413	0.12062473
May 2022	0.08129443	0.05387806	0.10871080	0.03936472	0.12322414
Jun 2022	0.08129443	0.05227779	0.11031107	0.03691730	0.12567156
Jul 2022	0.08129443	0.05076127	0.11182759	0.03459798	0.12799087
Aug 2022	0.08129443	0.04931658	0.11327228	0.03238853	0.13020032

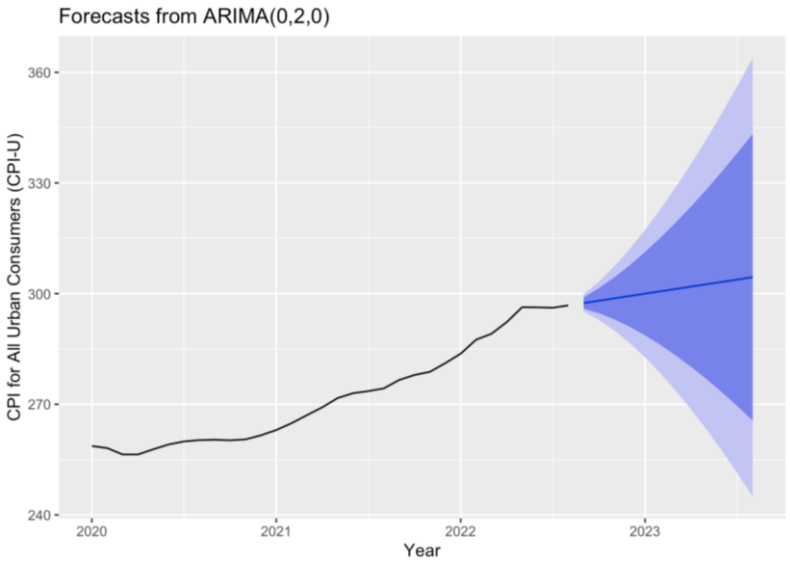

Fig. 8 Monthly CPI forecast plot for 12 lags (Photo credit: Original)

Table 2. Monthly CPI forecast for 12 lags

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Sep 2022	297.445	295.9202	298.9698	295.1131	299.7769
Oct 2022	298.082	294.6725	301.4915	292.8677	303.2963
Nov 2022	298.719	293.0139	304.4241	289.9937	307.4443
Dec 2022	299.356	291.0045	307.7075	286.5835	312.1285
Jan 2022	299.993	288.6850	311.3010	282.6990	317.2870
Feb 2022	300.630	286.0847	315.1753	278.3848	322.8752
Mar 2022	301.267	283.2257	319.3083	273.6753	328.8587
Apr 2022	301.904	280.1260	323.6820	268.5974	335.2106
May 2022	302.541	276.8000	328.2820	263.1736	341.9084
Jun 2022	303.178	273.2600	333.0960	257.4223	348.9337
Jul 2022	303.815	269.5163	338.1137	251.3596	356.2704
Aug 2022	304.452	265.5780	343.3260	244.9993	363.9047

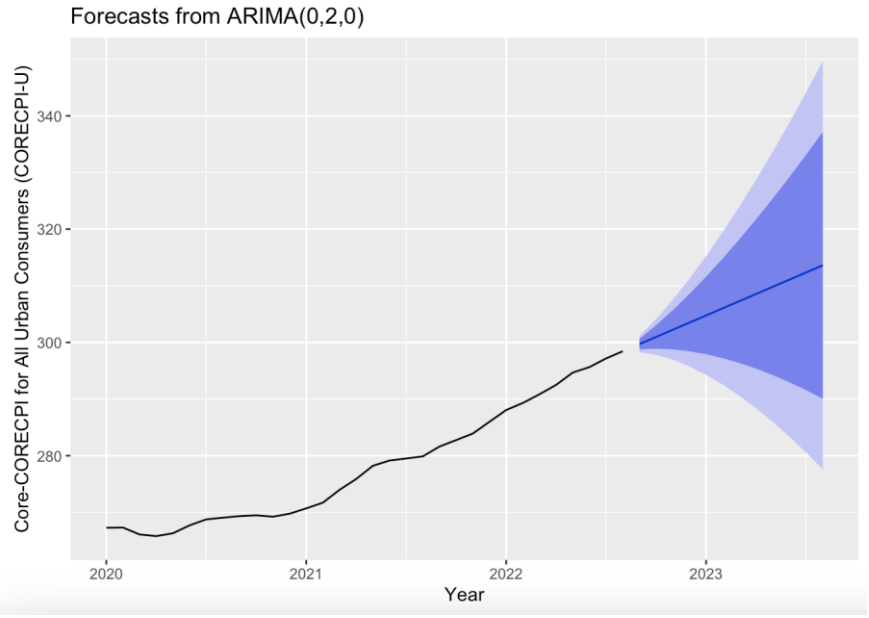

Fig. 9 Monthly Core-CPI forecast plot for 12 lags (Photo credit: Original)

Table 3. Monthly Core CPI forecast for 12 lags

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Sep 2022	299.706	298.7825	300.6295	298.2937	301.1183
Oct 2022	300.970	298.9051	303.0349	297.8120	304.1280
Nov 2022	302.234	298.7787	305.6893	296.9496	307.5184
Dec 2022	303.498	298.4400	308.5560	295.7624	311.2336
Jan 2022	304.762	297.9134	311.6106	294.2880	315.2360
Feb 2022	306.026	297.2167	314.8353	292.5534	319.4986
Mar 2022	307.290	296.3634	318.2166	290.5793	324.0007
Apr 2022	308.554	295.3643	321.7437	288.3821	328.7259
May 2022	309.818	294.2281	325.4079	285.9754	333.6606
Jun 2022	311.082	292.9623	329.2017	283.3704	338.7936
Jul 2022	312.346	291.5732	333.1188	280.5767	344.1153
Aug 2022	313.610	290.0662	337.1538	277.6029	349.6171

The forecast results are consistent with the previous analysis that inflation rate will remain high due to the economic outlook and monetary policy. For America's future inflation outlook, it is likely to leave the 0.02 era and at 0. 07 to 0.08 for a period. This is because even though supply chains and demand satisfaction are on track, several of the factors driving US inflation will not likely be eliminated in the next few years. In addition, uncertain factors, first, the continuation of the Russia-Ukraine conflict will continue to affect the price level of energy and food. Secondly, the development of deglobalization would continue to affect the cost of production, which depends on the subsequent development of the CN-US trade war. Therefore, although the Federal Reserve hopes to keep the inflation rate within an acceptable range in the short to medium term by tightening monetary policy, it is difficult for the inflation rate to return to the 0.02 level in the short term.

Supply chain repairs and lower shipping prices may slowdown in CPI growth, but commodity prices are unlikely to significantly return to pre-pandemic levels. First, in the food and energy subcategories, the fluctuations from external influences still significant, and the market prices will remain high due to international uncertainties. Second, as the current wage level in the U.S. is increasing, labor costs continue to push up the price level. Because the price of services is more affected by wages, and the impact of inflation on the price of domestic services would be greater than that of goods. This is due to substantial amount of trade in services takes place locally, and the share of trade in imported services is not large. In addition, the rising domestic wage trend and inflation will keep the service price high, that causing the CPI growth rate not easy to slow down. Unfortunately, although wages continue to rise, it has not kept pace with inflation for more than a year [10]. Therefore, rising wages have pushed up the price of services without raising real incomes. Third, for physical goods, the price elasticity of demand is lower than for energy and food, hence the increasing trend is more difficult to be slow. Core-CPI, comparing to CPI, will be more stable because energy and food are not included.

To reduce inflation rate, it is recommended that slightly increasing interest rate, focusing on rebuilding energy and food supply chains and considering a return to globalization. For policymakers, raising interest rates is a quick way to withdraw currency, but there are few spaces for maneuver after multiple increases. And it's important to note that the rising prices is due to a shortage of supply not due to a monetary problem, thus for the U.S, raising interest rates only solves the immediate problem. To end this inflation, it is needed to consider addressing the energy and food supply chains, as well as rethinking tariff cuts. That is because the conflict has upended the recovering world trade order, especially in the energy and food supply chains, which causing Europe's food security and energy security are under major threat [11]. Due to the destruction of the old supply chain, Europe needs to re-establish a new trade route, that one alternative is imports from the U.S. While this has increased incomes in the United States, it has also contributed to the domestic price level. In addition, with high tariffs affecting the prices of imported products, although the supply chain of domestic products is

recovering, it has not yet recovered to the pre-pandemic level. Therefore, a temporary reduction in tariffs would help to smooth the domestic imbalance between supply and demand and thus stabilize inflation.

4. Conclusion

Under pandemic, the U.S economy has suffered challenges, especially high inflation. The U.S. inflation rate is starting to rise rapidly in 2021 and reaching 0.09 at one point in 2022. The reasons for this are complex, mainly due to changes in the balance of supply and demand, the more currency plugging into market to prevent economic recession and external international political factors. The trend of CPI and Core CPI is similar as inflation rate, with both experiencing rapid increases after the pandemic. The reason for this is not only the same as inflation but the change in the consumption structure caused by the fall in consumer income and the change in consumption habits. The impact of the inflation is extensive, including reducing economic growth, income distribution and real purchasing power. With the interest rate hike policy to cope with inflation would increase the risk of economic recession. For low-income families, inflation would reduce their real income, and then affect their lives.

According to the forecast analysis, the inflation rate of the United States will hardly recover to 0.02 in the short term, and the growth rate of CPI and Core CPI is still high. This is because it needs time for recovering supply chains and re-balancing supply and demand. However, after some rate hikes, there is not much room for further increases, so it is suggested that the U.S. could slow inflation by fixing the international supply chain and temporarily lowering tariffs. The effects of the pandemic may be continuous for years, and external shocks that cannot be predicted in future. To counter the negative effects of the pandemic and these shocks, it is critical to dynamically adjust policy to address the real causes, just considering raising interest rates is not the most important tool for tackling inflation. If it is possible to further research the price index changes of more detailed categories of commodities, it would be more effective to find a solution to tame inflation.

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