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A Study of the Impact of U.S. Monetary Policy on WTI Crude Oil Prices in 2004 Based on ARIMA Forecasting Models

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Abstract:

Energy is an important basis for human survival and development, energy price stability is conducive to promoting economic development and maintaining the cost of living of residents, so it is necessary to explore the impact of energy price factors. This article for researching the impact of monetary policy on energy prices, based on the ARIMA model to predict the trend of WTI crude oil prices, through the comparison of forecasting crude oil prices with the actual crude oil prices, found that the tight monetary policy for crude oil prices has a positive impact. When the interest rate rises, the price of crude oil will also increase in the short term. This paper explores the impact of a single monetary policy factor on energy prices in the short run, excluding global economic turmoil and other factors such as geopolitics and wars. Furthermore, it provides some reference for monetary policy decisions, especially for energy market volatility in the short term.

Keywords: Energy price, monetary policy, ARIMA model, WTI crude oil price

1. Introduction

Energy prices are crucial for economic development. Low energy prices can promote production and consumption activities, reduce enterprise costs, improve competitiveness, and drive economic growth. On the contrary, high-energy prices may increase production costs, lead to inflation, slow economic growth, and have a negative impact on the financial situation of households and businesses. There are many factors that affect energy prices, such as i) global economic conditions: when the global economy is growing strongly, energy demand tends to increase, leading to higher energy prices. Conversely, when the global economy declines, energy demand decreases and prices may fall; ii) geopolitical issues: geopolitical events, such as wars, coups, sanctions, etc., may lead to disruptions in the supply of energy, affecting the global energy market and thus energy prices [1]; iii) policies issued by the government: governmental policies, subsidies, and taxes may also affect energy prices. Exchange rate fluctuations as well as interest rate fluctuations may affect energy prices [2]; iv) technological development: the introduction of new technologies may change the supply structure of energy. For example, the application of hydraulic fracturing has led to a significant increase in the production of shale gas and shale oil, which in turn has an impact on energy prices. According to the above review, there are many factors that affect energy prices, this article focuses on the impact of monetary policy on short-term energy prices.

In previous research on the relationship between energy prices and monetary policy, some findings do suggest that there is an interactive relationship between energy prices and monetary policy [1]. According to the findings, during the FOMC(Federal Open Market Committee) announcement period, the energy market experienced abnormal price fluctuations prior to the FOMC's scheduled announcements, and these fluctuations were related to the monetary policy decisions made by the FOMC on the second day[3]. On the one hand, some scholars argue that expansionary monetary policy has contributed to the increase in energy prices [4]. The increase in energy prices is usually attributed to accommodative monetary policy decisions and continued low interest rates [5]. On the other hand, some research results indicate that interest rate growth leads to a decline in asset prices, With a negative correlation between monetary policy and energy prices [6]. Some studies have also pointed out that by examining the contemporaneous effect of monetary policy shocks on oil prices using Fed funds futures data, no significant effect of federal funds rate shocks on oil prices was found [7]. Comparing to other U.S. assets, energy prices are not only affected by monetary policy, but also by a larger number of other factors [8].

In conclusion, according to previous studies by scholars, there are indeed more factors affecting the level of energy prices. Different scholars have different opinions on monetary policy as the only factor that has an impact on energy prices. The past research results show different conclusions that tight monetary policy has a positive, negative, and no significant effect on energy prices.

This paper intends to study the impact of monetary policy on energy prices and selects the data of WTI crude oil spot and futures prices from May 2004 to August 2004. Compared With other research results, there were no major political changes, geopolitical wars, or economic events during 2004, which excludes to a large extent the impact of other factors on energy prices. In this paper, building an ARIMA model to predict the WTI crude oil price trend in the two months after the monetary policy was announced on June 30, 2004. Then making a comparison with the actual crude oil price to assess the trend of crude oil price change under the effect of monetary policy. Thus, the results of the model show a clearer exploration of how monetary policy, as the single most important influence, affects the direction of energy prices in the short term.

The following parts of this paper are organized as follows: Section 2 describes the source of the data, the time series data stable test, and the building of the ARIMA model. Section 3 then analyzes the data results of the empirical study as well as illustrates the results predicted using the ARIMA model. Section 4 further discusses the results of this article and combines the findings of past research. Finally, this article will be summarized by giving the research result implications of the findings, and recommendations for monetary policymaking and response to energy price changes.

2. Research Design

2.1 Data source

The crude oil price data used for the empirical analysis comes from the public website investing.com, the fourth largest financial website in the world, which provides more reliable public data and news information around the world. The crude oil price in this article is selected from the WTI crude oil spot price, including daily closing data and weekly closing data to fully demonstrate the volatility of crude oil prices, data period covering June 22, 2004, to July 8, 2004. The reason for choosing this time period is that the influence of other factors on energy prices can be better excluded, as shown in Table 1 below, which shows that there were no wars, financial crises or other major events that affected the energy prices in the time period June 22, 2004, to July 8, 2004.

Table 1 Statistical Table of Events Affecting Energy Prices

Time Period	Monetary Policy	Events Description	Key Issues
Feb 1994 - Feb 1995	3% interest rate hike to 6%	A financial crisis occurred as a result of the dollar panic, during which Mexico abandoned its fixed exchange rate. The 6% interest rate on the dollar was maintained until July 1995, when it began to be reduced.	Financial crisis
Jun 1999 - Jun 2000	4.75% interest rate hike to 6.50%	The rate hike soon after punctured the 2000 Internet bubble and global financial turmoil. The US dollar 6.50% interest rate was maintained until 01/2001, when interest rate cuts began.	Internet bubble, global financial turmoil
Jun 2004 - Jun 2006	1% interest rate hike to 5.25%	The completion of the interest rate hike soon triggered the subprime mortgage crisis in the United States, which led to a financial tsunami. The 5.25% interest rate on the US dollar was maintained until September 2007, when interest rates began to be cut.	the subprime mortgage crisis in US
Dec 2015 - Dec 2018	0.25% interest rate hike to 2.25%	The Sensex tumbled again during the rate hike in the US-China trade war. The USD 2.25% rate was maintained until 08/2019 when the rate cuts began.	US-China trade war

Mar 2022 - Jul 2023	0% interest rate hike to 5.5%	The US dollar 5.50% interest rate has been maintained until now. During this period, there was a vicious U.S.-Ukraine conflict, trade friction between China and the U.S., economic turmoil in Argentina, huge inflation in the major economies of Europe and the U.S., and the Egyptian exchange rate plummeted by 40%.	U.S.-Ukraine conflict,trade friction between China and the U.S, economic turmoil in Argentina

In addition, this paper summarizes the U.S. monetary policy releases in 2004, as shown in Table 2 below, the FOMC raised the US Federal Funds Rate five times from 1% to 2.25% in 2004.

Table 2 US Federal Funds Rate

Date	Interest Rate (%)	Change(%)
2003-06-25	1.00%	-0.25%
2004-06-30	1.25%	0.25%
2004-08-10	1.50%	0.25%
2004-09-21	1.75%	0.25%
2004-11-10	2.00%	0.25%
2004-12-14	2.25%	0.25%

2.2 ADF Unit Root Test

The ADF (Augmented Dickey-Fuller) test is based on an extension of the Dickey-Fuller unit root test, which is used to determine whether there is a unit root in the time series data, to make a judgment of whether the data is stable. The null hypothesis of the ADF test is presented as a unit root, which means that the time series data is not stable. From the ADF test results Table 3, shows that the P-value of four groups log returns data is 0. Because the result of a P-value is less than 1, the conclusion should be given as the log returns for all groups reject the null hypothesis. The group's numbers which are listed in the tables are stable for empirical analysis.

Table 3 Weak stationarity test

	t	p
Daily data, spot price		
Ln value	-2.834	0.1849
1st order difference	-25.010	0.0000
Daily data, future price		
Ln value	-2.775	0.2062
1st order difference	-24.867	0.0000
Weekly data, spot price		
Ln value	-2.328	0.4184
1st order difference	-11.951	0.0000
2nd order difference	-19.702	0.0000
Weekly data, future price		
Ln value	-2.405	0.3771
1st order difference	-12.329	0.0000
2nd order difference	-20.120	0.0000

2.3 ARIMA Model

The full name of the ARIMA model is the autoregressive integrated moving average model, and this model is used for predicting future trends according to actual historical data. The essence of ARIMA (p, d, q) modeling is the combination of difference operations and ARMA modeling. Any non-stable series can be fitted with an ARMA model to the post-differential series if the post-differential stabilization can be achieved by differencing of appropriate order [9].

p: AR(p) represents the lagged values of the observations used in the ARIMA (p, d, q) model. The model equation is set up as shown below:

$$x_t = \varnothing_0 + \varnothing_1 x_{t-1} + \ldots + \varnothing_p x_{t-p} + a_t \quad (1)$$

d: stand for the order of the difference to transform the original non-stationary time series data to a stationary series.

q: MA(q) represents the lagged value of the error term used in the ARIMA (p, d, q) model. The model equation is set up as shown below:

$$x_t = c_0 + a_t - \theta_1 a_{t-1} - \ldots - \theta_q a_{t-q} \quad (2)$$

3. Empirical results

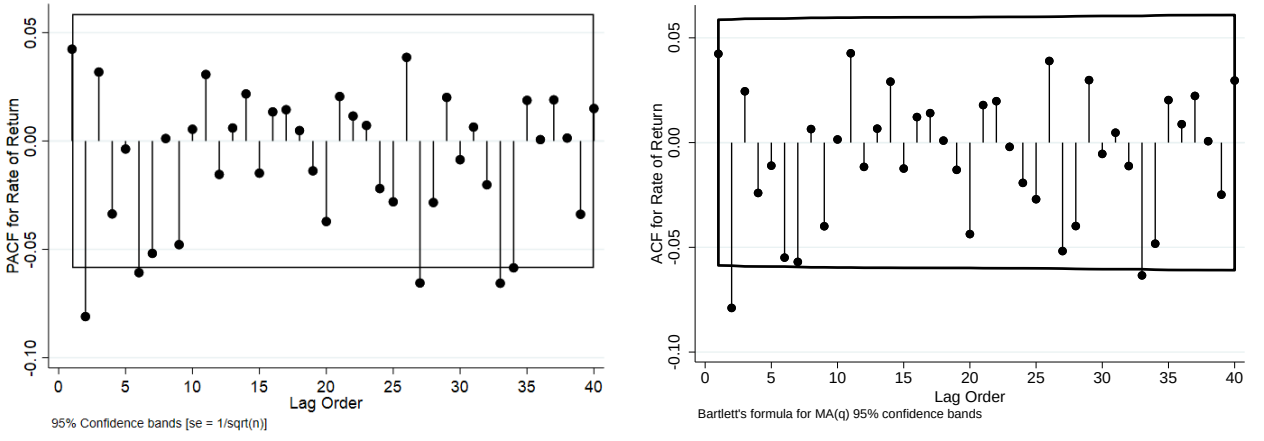
3.1 Order Determination and Residual Test

Based on the ARIMA Model, the first step is using the PACF (Partial Auto-Correlation Function) to order the daily logarithmic 1st order difference of crude oil sport price and crude oil future price. Then using the ACF (Auto-Correlation Function) to order the weekly logarithmic 2nd order difference of crude oil sport price and crude oil future price.

The order determination result of crude oil spot price is shown in Fig. 1., and the order determination result of crude oil future price is shown in Fig. 2. For the all-time series, the PACF image shows a truncated tail, the AR(p) model applies to the current time series and the lag order of the PACF truncation is the desired value of the parameter p. The ACF image presents a truncated state, the MA(q) model is applied to the current time series, and the lag order of the ACF truncation is the desired value of the parameter q.

PACF ACF

Daily data (1st order difference)



Weekly data (2nd order difference)

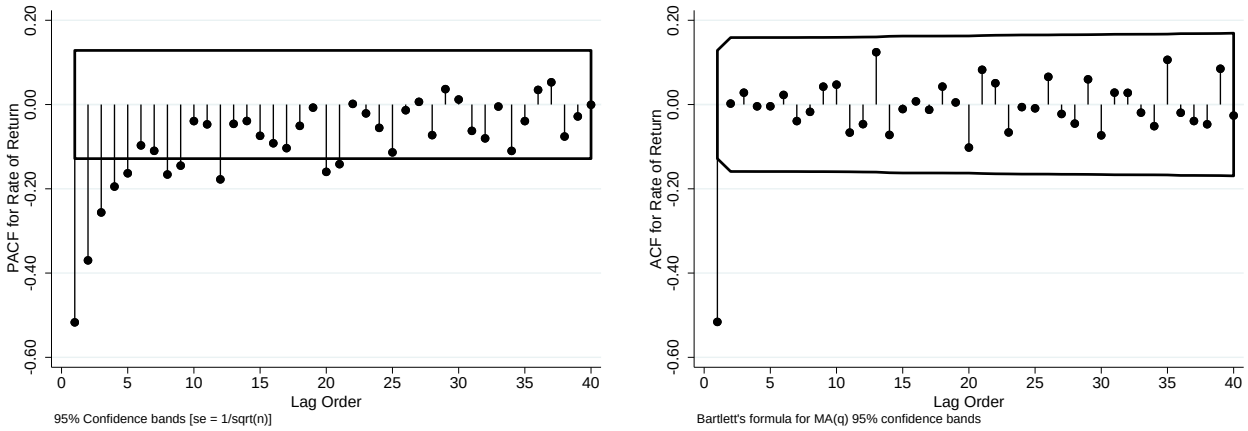
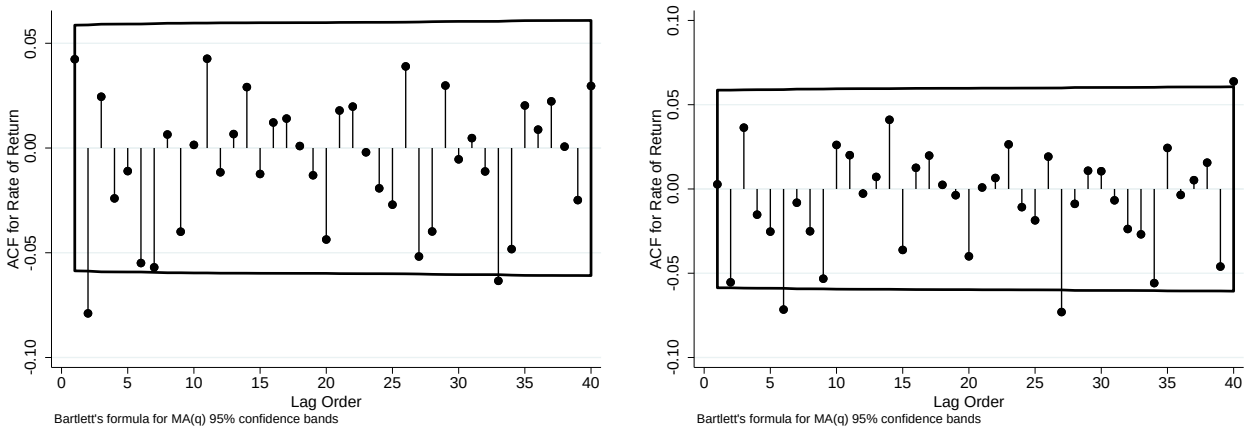


Figure 1 ARMA (p, q) identification, Spot price

According to Figure 1 and Figure 2 order results, four sets of data in fixed order and ARIMA(p,d,q) models are shown in Table 4. Furthermore, the residual test is performed as shown in Table 4.

PACF ACF

Daily data (1st order difference)



Weekly data (2nd order difference)

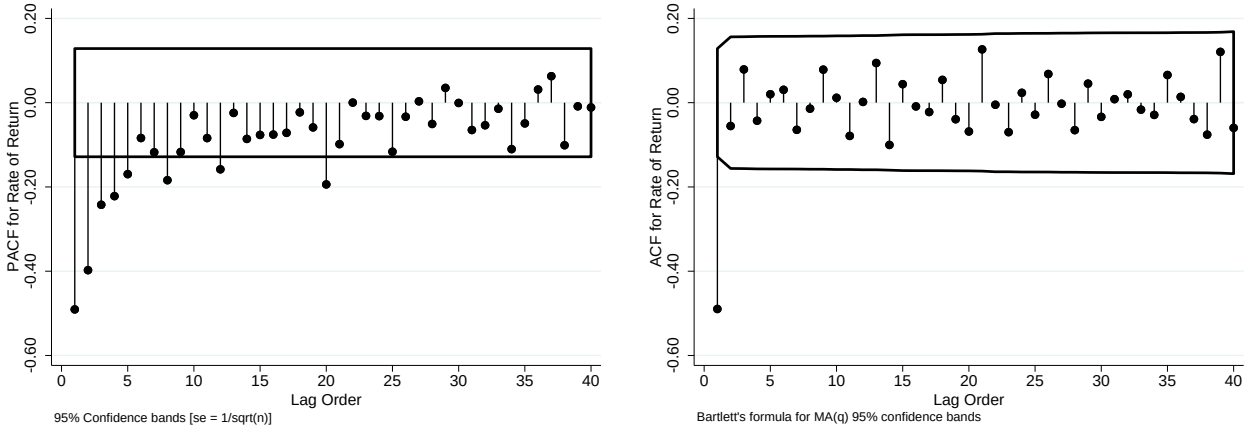


Figure 2 ARMA (p, q) identification, Future price

It is apparent that all the ARIMA models for spot price and future price have passed the residual test, and the error term is consistent with the white noise series.

Table 4 Residual test

Model	Portmanteau (Q) statistic	Prob > chi2
Spot price		
Daily- ARIMA (6,1,2)	36.0279	0.6497
Weekly- ARIMA (9,2,1)	29.1335	0.8980
Future price		
Daily- ARIMA (6,1,6)	35.0288	0.6933
Weekly- ARIMA (8,2,1)	32.8397	0.7818

3.2 Forecast Results and Interpretation

According to FOMC, in the year 2004, there were a total of 5 times the update of the US Federal Funds Rate, the statistical data is as follows in Figure 3. The US Federal Funds Rate kept increasing during the year 2004, from 1% on June 30, 2004, to 2.25% on December 14, 2004, and each time going up by 250 bps.

In the statistical range of crude oil prices from May 2, 2004 to August 22, 2004, there were two changes in the US Federal Funds Rate, namely a 250bp increase on June 30, and a 250bp increase on August 10, 2004.

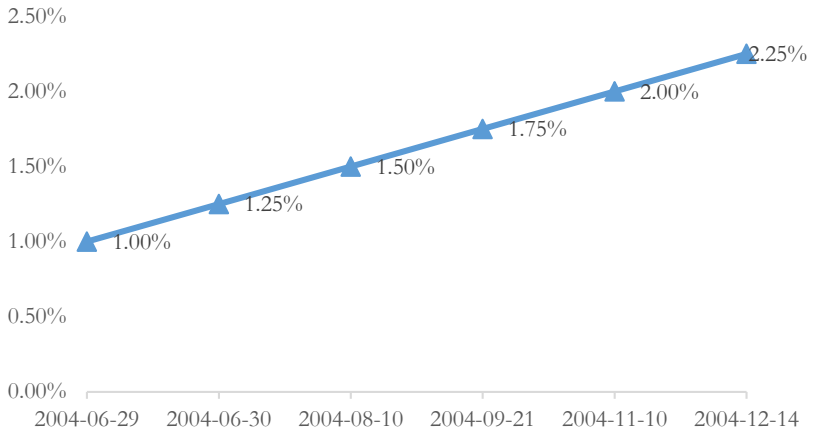


Figure 3 US Federal Funds Rate

After the ARIMA model building and passing the residuals test, the data forecasting was completed by using Stata for the period after the monetary policy shock of June 30, 2004, the comparison of actual price value (blue line) and simulation values (yellow line) shown in Figure 4 and Figure 5. The figures demonstrated the short-term impact of the monetary policy on WTI crude oil spot prices and future prices:

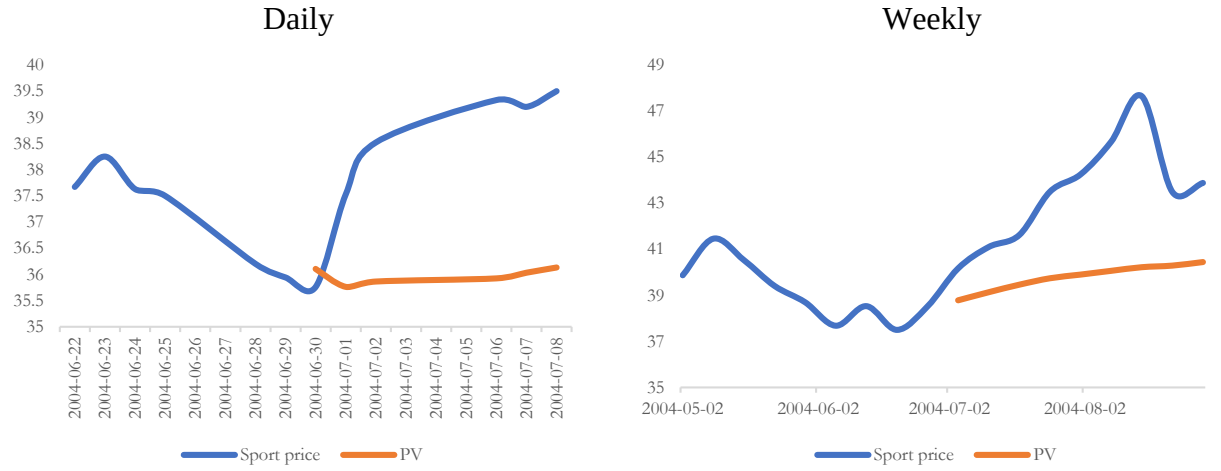


Figure 4 Simulation – spot price

As for WTI crude oil spot close price, making a comparison with the forecasting price, both daily and weekly actual price values showed a dramatic increase. The actual spot weekly price increased from $38.52 per barrel on June 27, 2004, to the peak value of $47.65 per barrel in the following month after releasing of the new monetary policy on June 30, and August 10. This indicates that the spot price of crude oil is positively affected by the tightened monetary policy of the rising federal funds rate in the United States.

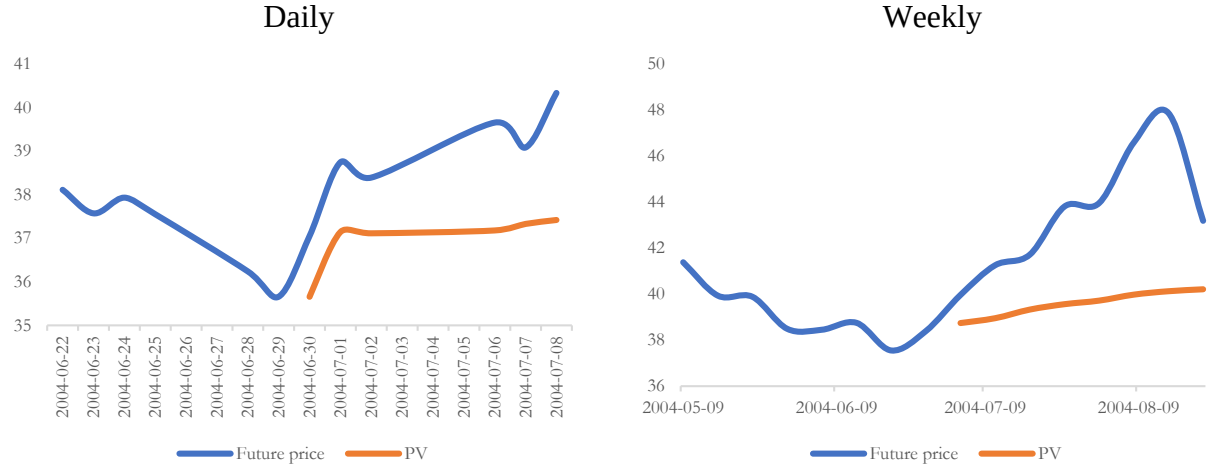


Figure 5 Simulation – Future price

After the new monetary policy announcement on June 30, 2004, the WTI crude oil future actual price value demonstrated a significant upward trend with a similar trend to the spot value compared to forecasting numbers. During the period of June 30 to August 15, 2004, the US Federal Funds Rate went up by 2.0% which motivated the WTI crude oil future price to rise to the highest level of $47.86 per barrel on August 10, 2004.

4. Discussion

The impact of monetary policy on energy prices is not direct, the theoretical link between energy markets and monetary policy can be understood through its impact on the wider economy, inflation. Energy prices, especially oil prices largely determine the overall level of inflation. The reason is that changes in energy prices directly affect production and transportation costs, which in turn affect the prices of goods and services across the economy [10]. The higher the volatility of oil prices, the higher the average inflation level [11]. According to the IS-PC Curve Model, to cope with the cost-push shock, a tight monetary policy is needed to further reduce inflation by lowering aggregate demand in the economy [12]. Therefore, to fully explore the relationship between monetary policy and energy prices, the impact of inflation needs to be considered more comprehensively.

This article confirms that monetary policy making does have some degree of impact on energy prices, this part is very much in line with more previous research findings. However, some research results also show that as energy prices rise monetary policy tightens, the inflation rate will draw down, thus bringing energy prices back down to the nominal level [4]. This study does not reflect the trend of energy prices declining with tight monetary policy, because to ensure that the single impact of monetary policy, using a shorter-term data span of only 3 months, while previous studies of the data interval is greater than 1 year. As a result, the response of energy prices to a tightening of monetary policy is characterized by a significant increase in the short term.

In addition, the ARIMA model has certain limitations and is only applicable to short-term data forecasting, and it is worthwhile to do further research on the medium- and long-term effects of monetary policy on energy prices.

5. Conclusion

This article builds an ARIMA model to predict the crude oil price from June to August 2004, and according to the results, the two interest rate hikes by the FOMC in June and August 2004 contributed to the continuous increase of the crude oil price by comparing the simulation crude oil price of the model with the actual crude oil price. Through the research, it can be concluded that in the absence of other political changes, geopolitical wars, and other major influencing events. The tight monetary policy has contributed to the further increase of crude oil prices in the short term.

The findings of the article inform monetary policy makers that the positive short-term impact on energy prices should be fully taken into account when designating a tight monetary policy to avoiding economic disequilibrium caused by large increases in energy prices. Similarly, as for energy users, such as energy-using commercial enterprises and urban residents, should respond adequately to short-term increases in energy prices caused by monetary policy after the issuance of FOMC tightening policies. In current complex social situations, such as the post-pandemic period and the current Russia-Ukraine war, how to formulate a reasonable monetary policy to stabilize energy prices and maintain stable economic development is a question that deserves in-depth consideration by the government as well as financial institutions.

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