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Beggar-Thy-Neighbor? The Spillover Effect of EMU Nominal Negative Interest Rate Policy on China's Monetary Policy

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Abstract

We estimate international spillover effects of EMU nominal negative interest rate policy (NIRP) on China's Monetary Policy. Using a LT-TVP-VAR we find that an expansionary EMU shock has short-term effects on Chinese financial basic variables and final targets. It leads to a Euro exchange rate depreciation, Chinese interest rate' rise and decrease of Chinese output, while other variables' responses are not stable. NIRP in the Euro zone has the negative spillover effects on Chinese monetary policy mainly because of expenditure switching effect of trade channel.

Keywords

EMU Nominal Negative Interest Rate Policy, Spillovers, China's Monetary Policy, Two-Tier System, LT-TVP-VAR

1. Introduction

Since 2012, the Danish Central Bank has lowered the interest rate of 7-day large time deposit to −0.2%, and 9 national and regional central banks, including the European Central Bank, Switzerland, Sweden and Japan, have introduced nominal negative interest rate policy (NIRP) and lowered the benchmark interest rate to negative, and the financial authorities of many countries around the world have implemented NIRR policy at the same time, and the scale of their economies is close to 1/4 of the world economy. Under the new epidemic, the U.S. entered the "zero interest rate era", and countries such as Britain, Russia and Australia also lowered their interest rates to cope with the impact of the epidemic on the economy, and this "innovative" monetary policy of NIRP has at-

tracted great attention from the theoretical and practical circles. The NIRP has challenged the traditional economic and financial theories and opened up a new field of central bank monetary policy tools. The series of problems caused by the NIRP has brought a whole new challenge to the development of the current monetary policy theory and practice. Frenkel (1983) points out that the spillover effects of monetary and fiscal policies originate from two important links between the domestic economy and the rest of the world's economic and trade exchanges and international capital flows [1]. And as an important trading partner, the EU and China's trade value reached $137.159 billion in January to February of 2022, which made EU as China's top trading partner. With the increasing external sensitivity of the Chinese economy, the study and analysis of the spillover effects of the NIRP in the Euro zone on China's monetary policy can help the central bank of China to formulate a reasonable monetary policy to cope with external shocks and achieve stable and healthy economic development.

This paper takes the NIRP in the Euro zone as a representative to analyze the spillover effect of NIRP on China's monetary policy. Firstly, the spillover channel of monetary policy is analyzed theoretically, and this paper divides the spillover channel into two layers. The NIRP firstly affects three rapid response indicators such as interest rate, exchange rate and asset price in China, and then affects the final monetary policy objectives (economic growth, full employment, price stability and balance of payments) in China through the interest rate channel, exchange rate channel and asset channel. This two-tier spillover channel forms the basic framework for the theoretical and empirical analysis of this paper.

According to the theoretical analysis of monetary policy spillover effects, this paper chooses LT-TVP-VAR as the empirical analysis tool and finds that the NIRP has a greater impact on interest rates and exchange rates, while asset prices (this paper mainly uses the stock market as a proxy for asset prices) are less significantly affected due to the regulated nature of China's capital and financial accounts. Since the level of marketization of interest rates in China needs to be developed and improved, and the exchange rate regime is managed to be pegged to a basket of currencies, the responses to shocks in interest rates and exchange rates are mainly short-term effects and their effects are not long-term in nature. Whereas Chinese economic growth, inflation and unemployment present positive short-term shocks to the NIRP in the Euro zone, the trade balance, on the contrary, presents negative shocks. Due to the complexity of factors affecting the final target of monetary policy, the spillover effect of NIRP in the Euro zone on the corresponding target in China is short-lived and unstable.

The marginal contributions of this paper are: 1) this paper divides the spillover transmission channels of NIRP in the Euro zone into two layers, and by analyzing the spillover effects of NIRP in the Euro zone in a hierarchical manner, the actual effects of different channels are observed to understand the main spillover channels of NIRP in the Euro zone on China's monetary policy; 2) according to the dynamic changes in China's economic environment after the implementation of accommodative monetary policy in the Euro zone, the A

non-linear parametric time-varying LT-TVP-VAR model is used to test the short-, medium- and long-term changes in the underlying variables and the final monetary policy target, so as to assess the spillover effects of the NIRP in the Euro zone on China's monetary policy and provide a comparable reference basis for China's monetary policy response.

2. Related Literature

With the development of world economic integration process, scholars not only consider domestic factors but also begin to pay attention to external factors when studying national economic growth. Fleming (1962) and Mundell (1963) constructed the famous MDF model to analyze the impact of international inter-capital flows, exchange rates and other factors on a country's macroeconomy [2] [3]. Kim (1999) finds that tight U.S. monetary policy has a negative short-term spillover effect on output in the G6 countries [4]. Kim (2001) further finds that an expansionary monetary policy shock through the channel of international capital markets leads to a significant increase in output of G6 countries [5]. After the financial crisis the US adopted quantitative easing (QE) and scholars began to focus on the spillover effects of the US QE on other countries. Fratzscher *et al.* (2018) found that the Fed's QE boosted global stock markets had a pro-cyclical effect on capital flows to emerging markets after studying the financial markets of the US and 65 other countries [6]. Bauer, Neely, Christopher (2014), on the other hand, focuses on the spillover effects of the Federal Reserve's Federal Reserve's large scale asset purchases (LSAPS) on developed countries such as the U.S., Canada, Australia, Germany, and Japan, and the article focuses on the spillover effects through DTS model to examine the effectiveness of the signaling channel and portfolio balance channel, the results show that the signaling effect is more significant in the U.S. and Canada, while the portfolio balance effect plays a greater role in Australia and Germany, and the portfolio balance effect in Japan has little impact on Japanese government bond yields, and the signaling effect is basically non-existent [7]. Bhattarai *et al.* (2015) found through BVAR model that the U.S. QE has spillover effects on emerging countries in terms of currency appreciation, declining long-term bond returns, rising stock markets, and inward capital flows [8]. Chen *et al.* (2016) use a global VECM (Global VECM) model to find positive spillover effects of U.S. unconventional monetary policy on credit, asset prices, and output in the Euro zone, as well as output in Brazil and China [9]. Using the SVECM model, Xu (2020) finds that tighter U.S. monetary policy led to higher output and lower prices in China after 2002 [10].

The literature on spillover effects in the Euro zone is relatively scarce. Most of these studies find positive spillover effects of unconventional monetary policy in the Euro zone. Fratzscher *et al.* (2016) find that unconventional monetary policy in the Euro zone has positive spillover effects on global equity prices and reduces sovereign risk and bank credit risk in G20 countries by boosting confidence [11]. Roman, Klara (2016) examine the spillover effects of unconventional monetary

policy in the Euro zone through PVARs model to investigate the spillover effects of unconventional monetary policies in the Euro zone on Central European countries such as the Czech Republic, Hungary and Poland. The results show that unconventional monetary policy in the Euro zone briefly drives up economic growth and inflation in these three countries [12]. Potjagailo (2016) uses the FAVAR model to study the spillover effects of Euro zone monetary policy on 14 European countries that are not in the Euro zone. Expansionary monetary policy in the Euro zone leads to an increase in output and a decrease in short-term interest rates and financial uncertainty in most of these countries. And the impact is greater for countries with higher openness. Prices show large regional differences, with Western European countries showing price increases and Central and Eastern Europe showing price decreases or no changes [13]. Babecká Kucharčuková *et al.* (2016) use the block-restricted VAR approach to compare the effects of conventional and unconventional monetary policy in the Euro zone on six EU countries (Czech Republic, Denmark, Hungary, Poland, Sweden and the UK) with spillover effects. The results show that conventional monetary policy affects inflation and output in these countries, unlike the spillover effects of unconventional monetary policy, which have spillover effects on output in only some countries, except for more rapid exchange rate movements, while inflation is barely affected [14]. Bluwstein (2016) chooses nine European countries as representatives of small open economies to study the unconventional monetary policy in the Euro zone on the nine countries' spillover effects. The results show that output spillovers are more significantly heterogeneous, with significant positive shocks in developed economies, insignificant results in CEE countries, and significant negative shocks in SEE countries, and inflation variables are similarly heterogeneous, with positive effects in CEE and SEE and negative effects in developed economies. The international transmission channel of conventional monetary policy is mainly the exchange rate channel, while the unconventional monetary policy has a poor exchange rate channel and a greater role for the financial channel [15]. Fukuda (2018) found that during the implementation of Japan's negative interest rate policy, the decline of Japan's long-term bond yield had a significant positive effect on Asian stock prices excluding South Korea [16]. Through FAVAR model, Spiegel and Tai (2018) found that compared with the interest rate shock in the United States, Japan's negative nominal interest rate policy not only had a small impact on Japan's economy, but also had a very limited impact on output and inflation in China and South Korea [17]. Based on the TVP-VAR model, Wang Ruohan and Ruan Jia (2020) found that Japan's monetary policy changes have a negative impact on China's output level mainly through the Sino-Japanese trade path, and improve China's output level through the monetary policy and asset price path [18].

From the existing literature, it can be seen that spillover effects are significantly present, and there are more obvious heterogeneous characteristics. Loose monetary policy tends to bring positive spillover effects on output across countries, and the more developed the economy and the more open the market, the

larger the spillover effects, while the spillover effects of inflation have greater variability. Most of the literature takes the spillover effects of unconventional monetary policy in the U.S. as the object of study, while unconventional monetary policy in Europe has also attracted the attention of some scholars, but the scope of the study mainly focuses on the analysis of the spillover effects on European countries or comparing the unconventional monetary policy in the Euro zone with that in the U.S. The spillover effects of NIRP in the Euro zone on larger emerging market countries such as China are currently very little research literature, so this paper has a certain complementary effect on the development of the literature.

3. Mechanism Analysis of the Spillover Effect of NIRP on China's Monetary Policy

The spillover channels of foreign monetary policy to other countries are usually considered to include international capital flow channel, exchange rate channel, trade channel, inflation channel, etc. Mackowiak (2007) studied that the spillover effects are mainly transmitted through the interest rate channel and trade channel [19]. Kazi (2013) argued that the transmission channels of spillover effects of monetary policy are mainly the interest rate, asset and trade channels [20]. Bräuning, Ivashina (2018) find that the spillover effects of monetary policy in developed countries are mainly generated through three channels such as risk-taking, portfolio rebalancing and market signals through time-varying coefficient models [21]. Albagli *et al.* (2019) identified the interest rate channel as the main transmission channel of monetary policy spillover effects in developed countries [22]. After analyzing based on the FAVAR model, Ding *et al.* (2012) argue that the Fed's monetary policy is mainly transmitted to China through interest rates, credit and trade [23]. Xu *et al.* (2020) examine the trade, interest rate and policy channels and argue that the price channel is the main transmission mechanism for the spillover effects of tight monetary policy from the U.S. to China [10]. Kazi (2013) analyzes that the factors influencing foreign monetary policy are divided into fast-moving and slow-moving factors, and the variables that can respond quickly to changes in foreign monetary policy are generally: interest rates, exchange rates and stock prices, etc. The response of factors such as employment and output usually has a certain lag [20]. Referring to Kazi (2013) [20], this paper divides the transmission mechanism of the NIRP spillover effects into two layers, with the Euro zone NIRP first affecting Chinese interest rates, stock prices, and exchange rates, which are the basic variables of monetary policy, and then eventually affecting the traditional ultimate objectives of monetary policy (economic growth, price stability, full employment, and balance of payments) through the interest rate channel, asset price channel, exchange rate channel, and other channels of monetary policy transmission (economic growth, price stability, full employment, and balance of payments).

First, when other countries or regions implement NIRP, with the continuous improvement of China's interest rate market mechanism, China's interest rates

will also emerge as a linkage mechanism, and the NIRP will drive down China's interest rates through the interest rate channel and the signaling channel. The NIRP will lead to a widening of the spread between the two countries over the bid-offer rate, and international arbitrage capital will flow from countries with NIRP policies to China with relatively high interest rates. Second, international arbitrage capital sells off the currency of the country with NIRP in the current period and shifts to the RMB, which causes the currency exchange rate of the country with NIRP to depreciate. Once again, NIRP usually leads to higher asset prices and lower investment yields in the home country, so investors turn their attention to other countries that can bring higher yields, international capital flows out of the implementing country and into China, so the demand for RMB in the foreign exchange market increases and the pressure for RMB appreciation rises. In order to maintain exchange rate stability, the NIRP of other countries will cause the People's Bank of China to buy foreign exchange and sell RMB in the foreign exchange market, the increase in foreign exchange accounts will cause an increase in macro capital market liquidity, although China has not fully liberalized under capital and finance, but QFII and other systems also provide corresponding channels for capital flows, thus driving up Chinese asset prices, capital markets are usually represented by The stock market and the real estate market are the typical representatives of asset prices that can react quickly, while the real estate market is more susceptible to policies than the stock market.

The second layer, 1) The interest rate channel. When China's interest rates are changed for the NIRP spillover effect, it will make investment and consumption rise through the interest rate channel and balance sheet channel, etc., which will affect outputs and prices, making outputs increase and prices rise. And the increase in investment and output can also alleviate a country's unemployment problem.

2) Asset portfolio channel. When Chinese capital market prices are affected by spillover, it makes investment and consumption rise through Tobin's Q and wealth channels, which leads to the output and price increase and unemployment rate decrease.

3) Price channel. The interest rate parity theory makes the currency of the country which implements NIRP depreciate, and the prices of Chinese imports measured in RMB fall. Since the share of intermediate goods in China's trade with other countries stays above 90% of total imports (Xu *et al.*, 2020) [10], the production costs of manufacturers fall, leading to an increase in output and a decrease in CPI.

4) Trade channel. According to the MDF model, the trade channel is mainly divided into the expenditure switching effect and the income absorption effect. Under the expenditure switching effect, the implementation of NIRP in the Euro zone leads to the depreciation of the euro, which causes an increase in Euro zone exports, thus bringing about the "beggar-thy-neighbor" effect, and since 2007, China has been the top importer of the EU for many years, and the increase in

Euro zone exports usually leads to an increase in Chinese imports. The increase in imports will worsen China's trade balance, leading to a decline in both output and prices; the income absorption effect refers to the implementation of a NIRP in the Euro zone, which will lead to a rise in the region's income and an increase in import demand, with China as the second largest exporter in the EU, the increase in EU import demand will lead to an increase in China's exports, ultimately leading to an increase in output and prices. The spillover channel of NIRP in the Euro zone forms the basic framework for the analysis in this paper.

4. Data and Methodology

4.1. Data

In terms of explanatory variable selection, short-term interest rate in the Euro zone is chosen as the proxy variable for the NIRP, which are the month-end values of overnight EURIBOR in the Euro zone. The policy base variables are selected as the month-end value of China's overnight SHIBOR and the exchange rate of euro against RMB, while Chinese CSI 300 index is selected as a proxy variable for the stock market. The final target variables of monetary policy are selected as the year-on-year value of China's industrial value added as a proxy for economic growth, the year-on-year value of the consumer price index as a proxy for inflation, the year-on-year value of urban unemployed as a proxy for the unemployment rate, and the trade balance between the EU and China as a proxy for the balance of payments. The data of CSI 300 index and the trade balance are standardized to eliminate the effect of the magnitude. All data comes from National Bureau of Statistics of China and the ECB, which are for the monthly indicators. The year-on-year value of urban unemployed is adjusted to a monthly indicator by the quadratic-average method since it is announced each quarter. All variables are list in Table 1. The sample spans from January 2010 until December 2021. The starting and ending dates have been chosen in order to 1) avoid major structural breaks, 2) avoid the high-volatility period following the Lehman crisis, 3) have a time period where NIRP was frequently used. All data in this paper came from WIND database.

Table 1. List of variables.

Nature of indicators	Indicator content	Abbreviation
Explanatory variable	overnight EURIBOR month-end value	EURIBOR
Policy base variables	overnight SHIBOR month-end value	SHIBOR
	exchange rate of Euro against RMB	EX
	Chinese CSI 300 Index	SPI
Final target variable	year-on-year value of China's industrial value added	IP
	year-on-year value of the consumer price index	CPI
	year-on-year value of urban unemployed	employment
	trade balance between the EU and China	TRADE

4.2. Empirical Design

In terms of model selection, this chapter chooses a time-varying vector autoregressive model with latent threshold parameters (LT-TVP-VAR). The transmission of monetary policy has time-varying characteristics, and most of the current literature uses time-varying parameter models in analyzing the spillover effects of monetary policy to other countries. While LT-TVP-VAR has time-varying parameters, its setting on the latent threshold can effectively smooth out the sharp fluctuations of the data, overcome the overfitting problem of the TVP-VAR model, reduce the estimation error of the covariance matrix, and improve the validity and robustness of the estimation results. Therefore, LT-TVP-VAR is chosen as the model used for the study. The specific models are divided into 2. Model 1 is a model of the impact of Euro zone NIRP on the base variables of Chinese monetary policy, and the variables include the proxy variables of Euro zone NIRP, Chinese short-term interest rate SHIBOR, the exchange rate and Chinese stock index. Model 2 is a model that examines the impact of Euro zone NIRP on China's final monetary policy target, and the variables include Euro zone NIRP proxy variables, Chinese industrial value added, CPI, unemployment and trade balance.

1) Smoothness test of variables and determination of lag order

Since the regression of non-stationary series may cause "pseudo-regression", the stationarity of each time series should be tested first. In this paper, the ADF unit root test is used, and the series of variables are smooth at least at 5% significance level. Based on the AIC principle of model lags, the lags of the model of the impact of NIRP on the policy base variables in the Euro zone are chosen to be of order 1, while the lags of the model of the impact on the final monetary policy target are chosen to be of order 2.

2) Estimation results under MCMC simulation method

We can see from **Table 2** and **Table 3** that in terms of convergence, none of the Geweke values of the parameters exceeded the 5% critical value of 1.96, indicating that the null hypothesis of convergence to the posterior distribution could not be rejected. The invalid factor is an important basis for judging the estimation effect of the model. Under the condition that the number of simulations is certain, the less the invalid factor is, the more reasonable the estimation result is. The largest invalid factors in the results in **Table 2** and **Table 3** are 275.51 and 242.62, and all other invalid factors are below 200. The invalid factors of MCMC estimation results are all small relative to the number of 10,000 simulations, so the posterior inference of LT-TVP_VAR model can be supported. In addition, the estimates of autoregressive coefficients Ω_{β}, Ω_{α} and Ω_{h} in the posterior results of each parameter are all less than 1 instead of 0, which satisfy the smoothness requirement of the autoregressive process, and in summary, the posterior distribution of the model parameter estimates is credible.

The acceptable rates of potential threshold values in **Table 4** are all higher than 9%, especially the threshold value of the coefficient of association, which is

higher than 30% for model 1, with a maximum of 82.4%, and higher than 30% for model 2, with a maximum of 43.1%. This implies that the original hypothesis of no threshold effect cannot be rejected statistically and that there is a threshold effect of Euro zone NIRP on the adjustment of the underlying variables and the final target of monetary policy in China. It is reasonable to use the LT-TVP-VAR model for the study.

Table 2. Results of MCMC estimation for Model 1.

Parameter	Mean	Stdev	95%L	95%U	Geweke	Inef.
μ_β	−0.0869	0.0516	−0.1678	−0.0203	0.000	21.13
ϕ_β	0.8363	0.0806	0.6434	0.9659	0.000	134.29
$(\Omega_\beta)_1$	0.0382	0.0036	0.0319	0.0460	0.000	98.56
μ_α	−0.3157	0.2546	−0.8874	0.1937	0.001	111.09
ϕ_α	0.8758	0.0966	0.6272	0.9918	0.451	99.30
$(\Omega_\alpha)_1$	0.0947	0.0410	0.0469	0.2058	0.328	187.67
μ_h	0.1107	0.1345	0.0064	0.4293	0.397	275.51
ϕ_h	0.9546	0.0754	0.7210	0.9992	0.371	116.47
$(\Omega_h)_1$	0.2464	0.1956	0.0526	0.7287	0.354	182.14
$(d_b)_1$	0.1389	0.1159	0.0060	0.3528	0.000	38.32
$(d_b)_2$	0.4762	0.2761	0.0227	0.9249	0.008	1.56
$(d_a)_1$	0.6817	0.5887	0.0196	2.1081	0.069	146.75
$(d_a)_2$	1.9118	1.7872	0.3287	4.2627	0.000	63.65

Table 3. Results of MCMC estimation for Model 2.

Parameter	Mean	Stdev	95%L	95%U	Geweke	Inef.
μ_β	−0.0111	0.0298	−0.0685	0.0435	0.106	13.35
ϕ_β	0.8135	0.0750	0.6492	0.9496	0.014	74.66
$(\Omega_\beta)_1$	0.0357	0.0029	0.0306	0.0419	0.886	67.92
μ_α	−0.1133	0.1582	−0.3952	0.2093	0.000	69.93
ϕ_α	0.8875	0.0743	0.7094	0.9882	0.110	65.52
$(\Omega_\alpha)_1$	0.0744	0.0202	0.0394	0.1178	0.000	242.62
μ_h	0.0344	0.0571	0.0048	0.1798	0.101	124.08
ϕ_h	0.9949	0.0052	0.9804	0.9997	0.012	69.45
$(\Omega_h)_1$	0.2277	0.0893	0.0917	0.4384	0.060	96.94
$(d_b)_1$	0.1032	0.0736	0.0046	0.2564	0.004	18.50
$(d_b)_2$	0.0537	0.0421	0.0022	0.1678	0.002	36.93
$(d_a)_1$	0.1794	0.2234	0.0074	0.7103	0.000	31.27
$(d_a)_2$	0.1239	0.0766	0.0052	0.2767	0.030	29.70

Table 4. Acceptability rate of potential threshold values (%).

	$(d_b)_1$	$(d_b)_2$	$(d_a)_1$	$(d_a)_2$
model 1	45.8	43.9	82.4	32.2
model 2	9.4	45.5	31.8	43.1

5. Empirical Results

5.1. Spillover Effects of Euro Zone NIRP on the Underlying Variables of Monetary Policy in China

Figure 1 and Figure 2 depict the time-varying response plots of the base and final target variables of monetary policy in China to the Euro zone interest rate, which represent the impulse responses of a unit standard deviation shock to other variables after a specific and identical time interval. In this paper, the impulse response durations of 4, 8 and 12 periods are chosen to represent the short, medium-and long-term effects. The black solid line in each of the following figures indicates a 4-period lag, the long dashed line indicates an 8-period lag, and the short dashed line indicates a 12-period lag. The graphs show that the short-term effects of the impulse response plots for each variable are larger than the medium- and long-term effects, while the medium-and long-term effects basically overlap with the zero line, indicating that the spillover effects of Euro zone NIRP on China are not long-term in nature.

The impulse response of Chinese interest rates to the interest rate of Euro zone in the second column, first row of Figure 1 shows that the impact of the interest rate of Euro zone on Chinese interest rates, which shows a positive shock relationship, that is, a decrease in the interest rate of Euro zone leads to a decrease in Chinese interest rates. There are large differences in the impulse responses of the three periods in the figure and the results are not robust, where the short-term effects are much larger than the medium-and long-term effects, and the medium-and long-term effects only have weak positive shocks around 2010 and 2017 and basically zero at other times. Since 2010 Euro zone implemented a series of QE policies such as the guaranteed bond purchase program and the securities market program during the European debt crisis, and the effects are more significant. As shown in the Figure 1, the shock response of the Euro zone to our interest rate during the European debt crisis formed an extreme value, the shock change was 0.085%. In 2014 the Euro zone implemented a NIRP, the corresponding impulse response also rose slightly to form a phase extreme value, and the shock change was 0.01%. European Central Bank began to adopt the NIRP and QE in 2015, and in 2017 QE reached its maximum, and the spillover effect of Euro zone interest rates on China's interest rates continued to rise, corresponding to the rise in the impulse response value in the graph and the formation of a significant phase crest, with the magnitude of the shock change rising to 0.05%. With the gradual contraction and rollout of QE, the impulse response values also start to show a downward trend.

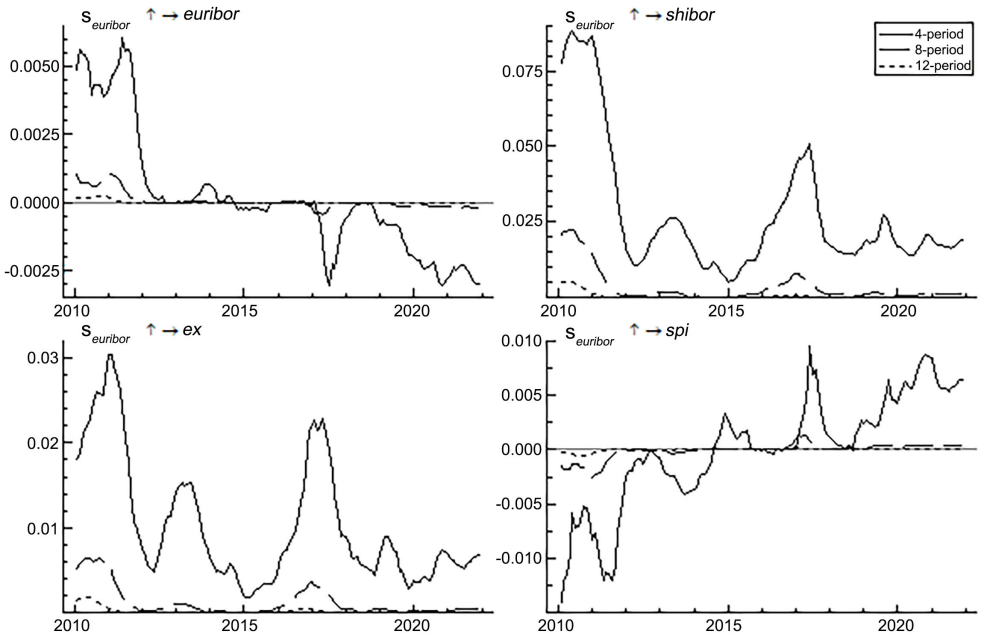

Figure 1. Time-varying response diagram of Model 1.

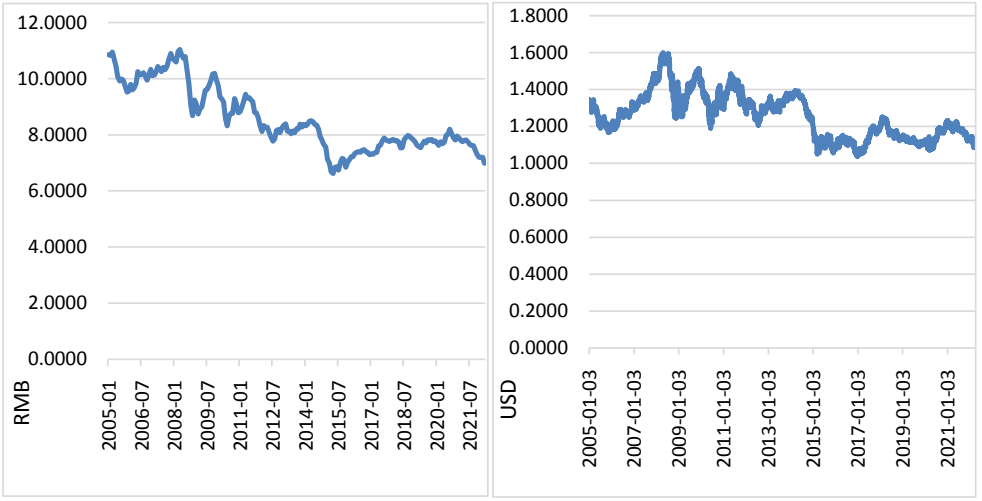

Figure 2. Exchange rates of euro against RMB and USD.

Looking at the impact of the interest rate of Euro zone on China's exchange rate in the first column, second row of Figure 1, the three-period impulse response is a stable positive shock effect. The fall of the interest rate of Euro zone is accompanied by a fall in the exchange rate of the euro against the RMB, that is, a depreciation of the euro and an appreciation of the RMB. Comparing the left panel of Figure 2, the exchange rate of euro against RMB forms a more significant downward trend in mid-2014, and the right panel of Figure 3 shows a similar change of euro against dollar, indicating that the RMB exchange rate reflects the change in demand in the foreign exchange market. Similar to the impulse response plot on China's interest rate, the shock of the European Central Bank's QE monetary policy during the European debt crisis in 2010 formed an

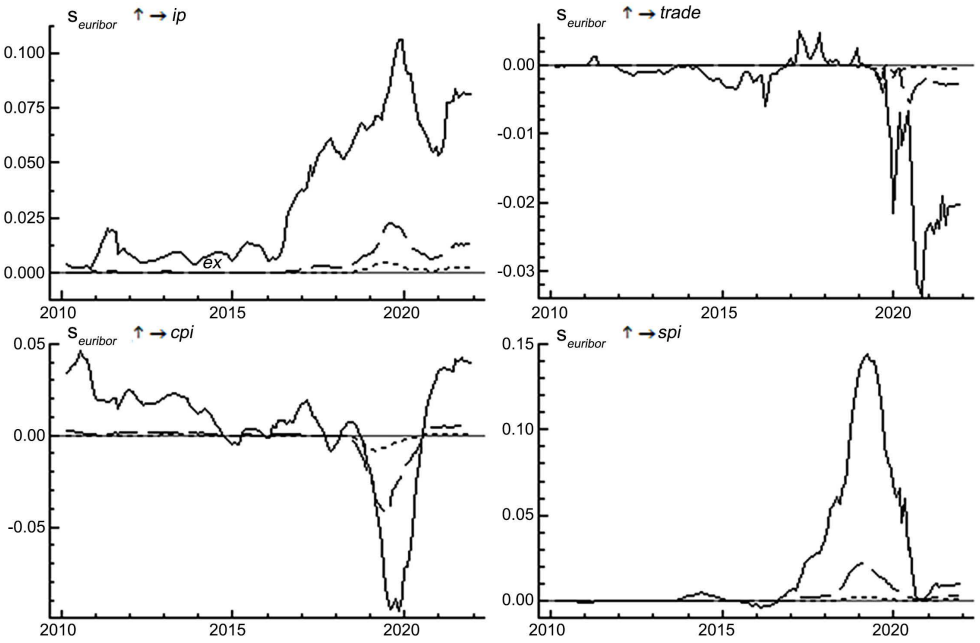

Figure 3. Time-varying response diagram of Model 2.

extreme value on our exchange rate, with a shock change of 0.03%. After the implementation of a NIRP in the Euro zone in 2014, the positive impact of the Euro zone interest rate on our exchange rate strengthened somewhat, with a shock change of 0.006%, and in 2017, the exchange rate impulse response formed a phase crest with a shock variation of 0.022%. This shows that the NIRP in the Euro zone has a positive spillover effect on our exchange rate, with a smaller impact than the superimposed effect of NIRP and QE. And then due to the slowdown in China's domestic economic development, foreign direct investment increased, short-term capital outflows. Those comprehensive factors make China's RMB appreciation rate dropped significantly.

The second row, second column of **Figure 1** show the impulse response plots of Chinese stock market to the interest rate of Euro zone. As seen in the figure, the three impulse response plots vary widely, the results are time-varying, and the effects are not robust. In 2010 the Euro central bank implemented a series of quantitative monetary policies in the Euro zone, which showed a significant negative spillover effect on the Chinese stock market, with a shock variation of −0.015%. In 2014, which is the start of the NIRP in the Euro zone, the shock variation is only −0.005%. The factors affecting the stock market are intricate, and in the second half of 2014, China kept cutting interest rates and implementing an accommodative monetary policy, which led to a narrowing of the difference between domestic and foreign bond yields. In 2014, the U.S. ended QE and entered the interest rate hiking cycle, and the expectation of RMB devaluation reduced the future returns of Chinese investments, so international capital continued to flow out of the Chinese capital market. In 2014 inflows to China's stock and bond markets have shown a declining trend since the second half of

2014. Combined with the continued decline in global energy prices in 2015, international capital investment has tended to be conservative, leading to a sharp decline in the Chinese equity market, which is shown in the graph as a pull-up in the impulse response chart. In 2015, due to the continued decline in global energy prices, international capital investment tends to be conservative, leading to a significant drop in the Chinese stock market, which is shown in the graph as a pull-up in the impulse response diagram.

5.2. Spillover Effects of Euro Zone NIRP on the Final Target Variable of Monetary Policy in China

Figure 3 which is the time-varying response of the final target variables of Chinese monetary policy to Euro zone interest rates shows that the short-term effect is significantly larger than the medium-and long-term effect, and the medium-and long-term effect are basically zero during the period when the NIRP was implemented in the Euro zone, which means that the NIRP in the Euro zone has a short-term effect on the final target of monetary policy in China, but has not a long-term effect.

The first column，first row and the first column，second row of Figure 3 show a plot of the impulse response of China's economic growth (or output) and inflation to Euro zone interest rate, respectively. The graphs show that the medium-and long-term effects on output are essentially zero until 2017, and the short-term response trend is highly variable, showing a non-time-varying positive shock, that is, a decline in Euro zone interest rates is accompanied by a decline in China's economic growth rate. Despite the positive spillover effect of the NIRP to Chinese interest rates, the effect is short-lived and very limited due to the existence of capital controls on the financial account in China, and thus it cannot affect domestic investment and consumption through the interest rate channel. According to the MDF model, the implementation of a NIRP in the Euro zone leads to the depreciation of the euro, and the expenditure switching effect increases Euro zone exports and Chinese imports, thus worsening China's trade balance and eventually leading to a decline in China's output and price levels; the income absorption effect, on the other hand, increases import demand because of rising Euro zone income, bringing about an increase in Chinese exports and eventually making output and prices rise. Figure 4 shows the import and export of the Euro zone to China, from which we can see that after the implementation of the NIRP in the Euro zone, both imports and exports of the Euro zone to China show a slow upward trend, and the expenditure switching effect and the income absorption effect may both take effect. Output and price changes in the model are in the same direction, and both are positive shocks, so the spillover effect of the NIRP in the Euro zone on China's output is mainly realized through the expenditure switching effect of the trade channel. After the financial crisis, economic growth in various countries was sluggish, and China's economy was also dragged down, as shown in Figure 5, the development rate

showed a rapid decline in 2008 and 2009. The GDP growth rate was adjusted to below 8% from 2012. Impulse response plots form phase extremes during the implementation of quantitative monetary policy in the Euro zone in 2011. In 2014, the ECB implemented a NIRP, and the impulse response plot shows a positive shock with a shock change of about 0.0125%, but since the spillover effect on China's spillover effects on economic variables does not have long-term effects, so there is no significant shock to China's economic growth. After 2016 China enters a period of three economic periods, the impulse response plot shows an increase in the magnitude of change, while the shock change in 2017 amounted to about 0.0375% when QE was maximized. The positive shock reaches an extreme value of 0.1% in 2020 under the COVID-19 epidemic. This shows that the factors affecting China's economic growth are intricate and complex, and the impact of the NIRP in the Euro zone to China's economic growth is not significant under a combination of factors.

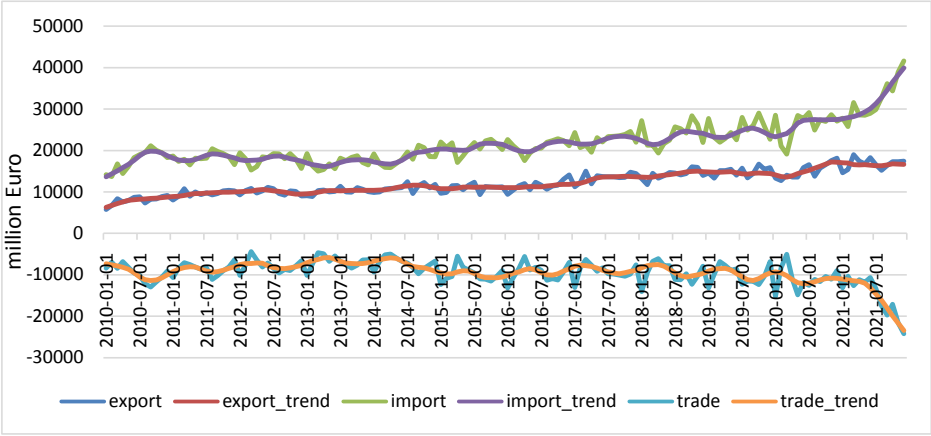

Figure 4. Map of eurozone import and export trade to mainland China.

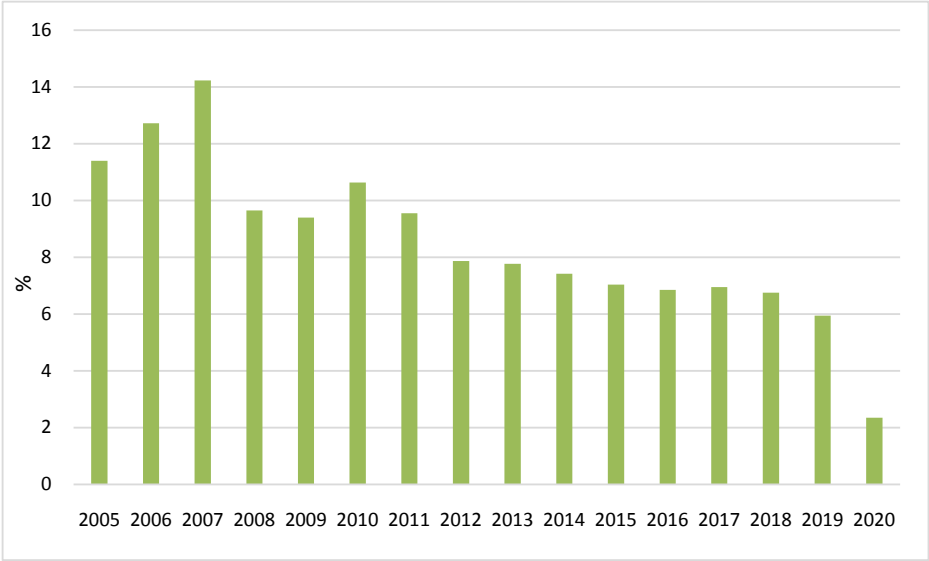

Figure 5. China's GDP growth rate since 2005.

The first column, second row of Figure 3 represents a time-varying plot of the response of Chinese inflation to the interest rate policy shock in the Euro zone. The figure shows that the medium-and long-term effects of Euro zone interest rates on Chinese inflation are almost zero, and the short-term effects are mainly positive shocks, that means that Chinese inflation decreases with the decline in Euro zone interest rates. The impulse response values started to decrease in 2014 with a shock variation of about 0.01%. From the previous elaboration, it is clear that the spillover effect of the NIRP in the Euro zone on China's economic growth is small, while the spillover effect on the exchange rate and import and export trade is significant. The implementation of the NIRP in the Euro zone leads to the depreciation of the euro and the appreciation of the RMB. In terms of trade, the appreciation of the RMB leads to lower prices for Chinese imports, which, together with the sharp fall in crude oil prices in the international market in 2014, leads to a decline in the Chinese consumer price index, corresponding to the middle part of the circle in Figure 6. As seen in the Figure 3, the impulse response plots all show phase extremes when quantitative monetary policy is implemented (2011) or expanded in the Euro zone (2017), and the magnitude of the shock changes is significantly larger than that of NIRP implementation period in 2014. In 2019 a structural price increase appears in China due to the rise in some food prices, and the impulse response plot shows a negative extreme.

The impulse response plot of the trade balance between China and the EU to interest rate of Euro zone in the second column, first row of Figure 3 shows that the shock response of the trade balance is mainly negative, but the effect is unstable. The impulse response of the interest rate of Euro zone on the trade balance between the two regions from 2014 shows a negative shock with a shock variation of about −0.04%, and the impulse response forms a phase trough in 2016. According to the income absorption effect of the MDF model, the implementation of a NIRP in the Euro zone leads to an increase in Euro zone income and thus a rise in Euro zone external demand and an increase in Chinese exports. Specifically, domestic and foreign income is the factor that promotes China's import and export to the EU, and the income elasticity of the EU is larger than

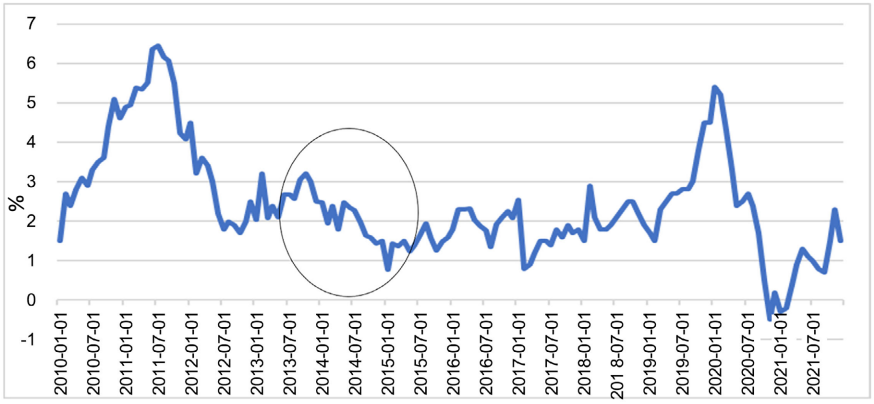

Figure 6. CPI in China since 2010.

that of China, and the impact of the EU demand factor on the trade between the two sides is much larger than that of the Chinese demand factor (Xiong Yan *et al.*, 2013). The implementation of the NIRP in the Euro zone released the signals of loose monetary policy, which gave a welcome fillip to income expectations , as evidenced by increased demand in foreign markets. On the July of 2014, China's exports to the EU rose by 17.02% and imports rose only by 7.6%, which means that the trade balance expanded. In 2016, the EU economy emerged from the financial crisis and European debt crisis, GDP returned to the pre-crisis level and the economy recovered, which greatly boosted market confidence. Economic confidence index and PMI index reached the highest level in recent years. in March of 2016, China's exports to the EU stopped falling and rose to 17.94%, and imports increased by 1.38% year-on-year. The above factors make the impulse response of the trade balance form a phase extreme. While the impulse response plots show positive phase extremes in 2011 and 2017, the trade balance shrinks as interest rates decrease, as in October 2011 when China's imports to the EU increased by 6.69% while exports decreased by 0.03%. During the maximization of the QE of the ECB in 2017, the euro exchange rate continued to fluctuate at low levels (see **Figure 3**), and the depreciation of the euro, which negatively affected our import and export trade, reduced the trade balance and shifted the impulse response plot to a positive shock and formed an extreme value in the figure. This shows that the negative impact of the eurozone's quantitative monetary policy on China's import and export trade is even greater. In 2020 a larger shock exits in imports and exports due to the COVID-19 epidemic.

The second row, second column of **Figure 3** show the time-varying response of Chinese unemployment to Euro zone interest rate. The impulse responses alternate positively and negatively and have small shock variations before 2017, and the impulse response plot stabilizes as a positive shock response then. Among them, the long-term effect is essentially zero, the short- and medium-term trends are essentially similar, and the short-term effects are larger than the medium-term effects. The global economic downturn after the 2008 financial crisis and the downward trend in China's economic situation also started, triggering cyclical unemployment and thus a persistently high unemployment rate. The Chinese unemployment rate shows a positive relationship to the shock of the NIRP in the Euro zone in 2014, with a shock change of about 0.005%. As nominal interest rates in the Euro zone fall into negative territory, China's unemployment rate also falls. The implementation of the NIRP in the Euro zone increases China's exports through an income absorption effect, and the increase in exports raises the employment level. However, as seen in the figure, the effect is very short-lived, with the impulse response of the unemployment rate returning to the zero line in 2015. Negative spillover effects on Chinese output and prices increases when QE was maximized in the Euro zone in 2017. But China's domestic economic growth picks up, driving the unemployment rate down significantly. The impact of the ECB's NIRP on China's employment level is limited

due to the complex factors affecting the employment rate during China's economic transition.

As can be seen in Figure 3, the expenditure switching effect of the trade channel of the NIRP in the Euro zone is larger than the income absorption effect, and China's economic growth, inflation and unemployment present a positive short-term shock to the NIRP in the Euro zone, while the trade balance, on the contrary, presents a negative shock. Despite the growth of Chinese exports to the Euro zone under the NIRP, the EU-28 countries invested RMB 42.07 billion (equivalent to USD 6.85 billion) in China in 2014, down 5.3% year-on-year. Meanwhile, China's capital and financial account (including net errors and omissions) had a deficit of RMB 559.5 billion in 2014, and international reserve assets decreased by RMB 184.4 billion. According to UBS Securities (2015), in addition to FDI, capital outflows were estimated to be as high as US$324 billion in 2014, and China experienced a decrease in EU investment and a large capital outflow phenomenon domestically, and the decrease in domestic capital will inevitably have a negative impact on output, so that after the implementation of the NIRP in the Euro zone, despite the growth in China's exports to the Euro zone, they were reduced by the decrease in foreign investment and capital outflows The output of China shows a downward trend, despite the growth of Chinese exports to the Euro zone after the implementation of the negative interest rate policy. Due to the complexity of factors affecting the ultimate goal of monetary policy, the spillover effect of the NIRP in the Euro zone on the corresponding target in China is short-lived and unstable.

6. Conclusions

We empirically examine the spillover effects of the NIRP implemented by the ECB using the LT-TVP-VAR model. Despite the obvious importance of this topic for policy, the international spillover effects of the NIRP in the Euro zone have been rarely examined.

We divide the spillover effects of the NIRP in the Euro zone into two layers. Firstly the Euro zone NIRP affects Chinese interest rates, stock prices, and exchange rates, which are the basic variables of monetary policy, and secondly affects the traditional ultimate objectives of monetary policy (economic growth, price stability, full employment, and balance of payments) through spillover channels. The following empirical study also follows this two-tier system.

We use monthly data for 2010-2021 and examine the impact on two-tier variables, that is, the dynamic shocks of Euro zone interest rate on Chinese interbank offering rates, exchange rate of euro to RMB and the Chinese stock market, the dynamic shocks of Euro zone interest rate on Chinese output, prices, import and export trade and unemployment. The results show that the NIRP in the Euro zone has significant short-term positive spillover effects on China's interest rates and exchange rates, with the most significant spillover effect on interest rates, while the negative short-term spillover effect on China's stock market is both weak and unstable. And the spillover effects of the NIRP on interest rates,

exchange rates and the stock market are smaller than the superimposed spillover effect of NIRP and QE.

Theoretically, the interest rate channel of NIRP will drive other countries' outputs and prices increase. China has basically completed the process of interest rate marketization, but the degree of interest rate marketization has yet to be developed, therefore, the interest rate channel of spillover is not yet open. The impact of NIRP on Chinese stock market is very limited, so the role of the asset portfolio channel is also very limited. Therefore, the spillover effect of NIRP in the Euro zone to China is mainly through the price channel and the trade channel. China shows a double decline in output and price. Based on it, we can conclude that the trade channel plays a major role and the expenditure switching effect is larger than the income absorption effect, which leads to a short-term positive shock of Chinese economic growth, inflation and unemployment, while on the other hand, the trade balance presents a negative shock. And according to Figure 1 and Figure 3, the short-term spillover effect of quantitative monetary policy in the Euro zone is higher than the short-term effect of negative nominal interest rate policy, while the short-term superposition effect of the two is more significant. Due to the complex factors affecting the ultimate goal of monetary policy, the spillover effect of NIRP in the Euro zone on the corresponding target in China is short-lived and unstable.

In the short run, the negative nominal interest rate policy in the Euro zone has a negative or "beggar-thy-neighbor" spillover effect on China's monetary policy, but the effect is short-lived and less influential. This is similar to the suggestion by You Yang, Ma Li, and He Yun (2020) that the Fed's monetary policy favors developed countries to the detriment of developing countries. However, in comparison, the spillover effect of the Fed's monetary policy is larger than that of the negative nominal interest rate policy in the Euro zone, and a similar conclusion is reached by Fratzscher (2016). With the increasing marketization of interest rates and openness under capital in China, the monetary policy of other countries is bound to produce greater spillover effects. Therefore, how to reduce the negative spillover effects of other countries' monetary policies in the future is one of the important objectives of central banks in developing countries.

Statements and Declarations

The authors declare that they have no competing financial interests. No funding was received to assist with the preparation of this manuscript.

Data Availability Statements

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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