

Transmission Channel and Effect Analysis of Denmark's Nominal Negative Interest Rate Policy

Lisha Zuo^{1,2}

¹*Institute of Finance, Jiangxi University of Finance and Economics, Nanchang, 330000, China*

²*Institute of Economics and Management, East China Jiaotong University, Nanchang, 330000, China
1254082203@qq.com*

Abstract: Denmark is considered to be the most successful example of implementing a nominal negative interest rate policy (NIRP). This paper examines the transmission and effects of the NIRP in Denmark through a TVP-SV-VAR model. The results show that the exchange rate channel of the NIRP in Denmark is effective while the NIRP increases exports and effectively promotes economic growth through Danish krone's depreciation. And the interest rate channel, the wealth channel and the asset portfolio channel plays a limited role. Denmark's NIRP is effective as it aims to ease the pressure of exchange rate appreciation.

Keywords: Denmark's NIRP, Transmission channels, Transmission effect, TVP-SV-VAR

1. Introduction

One of the basic assumptions of traditional economic theory is that the nominal interest rate has a natural zero lower bound, that is, the nominal interest rate must be positive. Interest rate is an important instrument of monetary policy regulation. The NIRP changed the market's expectation that the policy interest rate had a "zero interest rate floor", and raised the cost of holding funds by commercial banks, and directed funds to the real economy. The emergence of NIRP has broken the conventions of mainstream economics and impacted the basic theories of traditional financial research, and in recent years, NIRP has become an important topic of research for scholars at home and abroad. In this paper, we use the Danish NIRP as the object of study, with a view to providing a reference for Chinese monetary policy.

2. Literature review

Fisher (1930) first laid the logical foundation for the lower bound on interest rates, that is, interest rates naturally have a zero lower bound[1]. The interest rate cannot be negative, which has become one of the basic ideas of the mainstream economics. Goodfriend (2000) argues that NIRP is more effective than continued inflation targeting when inflation is already high enough (Buiters and Panigirtzoglou, 2003) [2][3]. Madaschi et al. (2017), by studying the case of Denmark and Sweden, conclude that net interest income remains essentially stable in Sweden under NIRP while it decreases only slightly in Denmark[4]. Khayat (2017) uses the MS-TVTP model for Denmark and finds that Unlike ordinary interest rate cuts, NIRP cause banks to increase capital outflows while relieving pressure on the appreciation of the Danish krone and achieving the monetary policy objective[5]. Some domestic scholars also found that NIRP can effectively achieve monetary policy objectives and should be used as a common monetary policy tool (Sun, 2017; Wang, Changyuan and Zhang, Hongyu, 2019)[6][7]. Li Jie et al. (2020) found that people's precautionary savings decreased when interest rates fell to negative levels, and the effect of interest rates on savings was dominated by substitution effects, and the effectiveness of monetary policy was further enhanced, thus verifying the effectiveness of NIRP[8].

Some scholars also hold a different view on this. Bassetto (2004) suggests that NIRP are not an equilibrium condition for market clearing, and if NIRP is simply implemented, it may have serious negative consequences for the economic system (Gnan and Beer, 2015; Palley, 2016; Siegel and Sexauer, 2017)[9][10][11][12]. Agarwal, Kimball (2015), Hannoun (2015) and Stiglitz (2016) all argue that NIRP affects the business models of banks and non-bank financial institutions such as insurance companies and pension funds, which can significantly curtail the earnings of financial institutions and pose a significant financial system stability risk[13][14][15]. Zeng et al. (2017) had conducted an empirical

study on the relationship between NIRP and bank risk in the European banking sector by selecting quarterly data of 100 banks in the euro area, and the results showed that negative market interest rates significantly increased the risk level of banks in the euro area[16]. Lu Chao et al. (2019) evaluated the NIRP and economic growth and had a very limited effect[17]. Xiong Qiyue and Wang Shujiao (2020) found that NIRP caused an increase in the precautionary motive of economic agents and a significant increase in the proportion of cash holdings, while the proportion of bank loans did not increase in the euro area by synthetic control method and found that this instrument did not stimulate significantly, making the lower operational efficiency of banks and the risk concentration of the financial system[18].

From a comprehensive view of the scholars, the negative attitude toward NIRP dominates the view. The results are also mixed as to whether the countries implementing NIRP use this tool to get out of the economic downturn or to suppress appreciation.

3. Background of the implementation of NIRP in Denmark

Table 1: Danish policy rate adjustment since 2012 Unit: %

time	Certificate of Deposit Rate	Discount Rate	Current-account Rate	Lending Rate
July 6th, 2012	-0.2	0	0	0.2
January 25th, 2013	-0.1	0	0	0.3
May 3rd, 2013	-0.1	0	0	0.2
April 25th, 2014	0.05	0	0	0.2
September 5th, 2014	-0.05	0	0	0.2
January 20th, 2015	-0.2	0	0	0.05
February 6th, 2015	-0.75	0	0	0.05
January 8th, 2016	-0.65	0	0	0.05
September 13th, 2019	-0.75	0	0	0.05
March 20th, 2020	-0.6	0	0	0.05
March 19th, 2021	-0.5	0	-0.5	-0.35
October 1st, 2021	-0.6	0	-0.6	-0.45
July 22nd, 2022	-0.1	0	-0.1	0.05

Source: Danmarks Nationalbank

The financial crisis in 2008 brought a huge impact on the world economy, and since then the world economy has slowed down, and in 2010 the European debt crisis, which eventually affected the entire eurozone, started from Greece. Domestic demand in the eurozone is sluggish and international trade is suppressed. The 2008 crisis also had a negative impact on the Danish economy, with GDP growth falling from 0.91% in 2007 to -4.91% in 2009. In Denmark, private consumption and business investment showed a slowdown, and the month-on-month trade retail sales have been negative for 26 consecutive months since May 2011, with domestic demand shrinking and market confidence low. In order to boost demand, the Danish government has introduced a series of loose fiscal policies such as tax reforms and flexible employment programs. Under the European debt crisis, Denmark, which is rated as a 3A degree, has naturally become a risk-averse capital transfer location within Europe. And significant capital inflows led to very strong pressure on the Danish krone to appreciate against the euro. Denmark has implemented a fixed exchange rate system pegged to the euro since the 1980s, which can provide an anchor for Denmark to maintain a stable low level of inflationary expectations. The Danish krone appreciation trend put a lot of pressure on the Danish government to implement the euro peg, especially after the Euro countries cut interest rates, so on July 5, 2012, the Danish central bank announced to reduce the large deposit rate to -0.2%, refinancing rate to 0.2%, rediscount rate to 0, with overnight deposit rate unchanged. Sweden has taken NIRP only as a temporary measure for 13 months in 2009, so Denmark is generally regarded as the first country to implement a NIRP. The Danish Central Bank establishes the policy rate by setting the deposit facility rate and the lending facility rate that the central bank offers to financial institutions. The Danish Central Bank influences money market interest rates by establishing the policy rate, which in turn influences market short-term and long-term interest rates and ultimately transmits to the monetary policy objective (the main monetary policy objective in Denmark is to maintain an inflation rate of around 2%). The adjustment of the Danish central bank's policy interest rate since 2012 is specified in Table 1, from which it can be seen that on April 25, 2014, the Danish government abandoned its NIRP as the European debt crisis wound down and conditions in Europe turned better, but only five months later, the appreciation pressure on the Danish krone forced the central bank to drag the rate back into the negative space again. In January 2015, the Danish Central Bank lowered the certificate of deposit rate to

-0.75%. On March 19, 2021, the Danish Central Bank set the overnight deposit rate and the one-week refinancing rate to negative values in order to improve market liquidity. At this point, the Danish central bank's policy interest rate was at zero or below, increasing the intensity of the NIRP.

4. Construction of the channel effect model of NIRP

As a complement to quantitative easing, NIRP is a charge imposed by the central bank on commercial banks, rather than on depositors. It helps guide commercial banks to put funds into the market and stimulate residential consumption and corporate investment, thus serving to raise the level of inflation and promote economic growth. There are four main channels of its transmission: First, the credit channel. NIRP is conducive to banks in order to reduce excess reserves and financing costs, thus to expand the scale of loans. However, after the implementation of NIRP, if commercial banks pass on the cost to customers and implement NIRP on retail deposits, although it will increase bank loans for lowering loan rates, it will also harm the interests of depositors; on the contrary, if commercial banks do not pass on the cost to depositors, but maintain or even increase loan rates, it will reduce the size of loans and weaken the transmission effect of negative interest rates on the real economy. Second, the asset price channel. NIRP is conducive to lowering the discount rate of asset cash flows and improving expectations of economic development, thus increasing the future rate of return on assets. Some of the funds will enter the asset market, driving up asset prices. Third, the wealth channel. the most direct effect of NIRP is to prompt residents to convert savings into consumption, rising consumer demand will improve business output, and raising the price level. Fourth, the exchange rate channel. NIRP may cause investors to sell their domestic currencies in favor of other higher-yielding overseas assets, leading to a depreciation of the local currency. A depreciation of the local currency can increase net exports, thus boosting economic growth and employment, while raising the level of inflation through higher prices of imported goods.

Based on the previous analysis, this paper tries to divide the process of monetary transmission analysis into two levels, one is to analyze the smoothness of transmission from NIRP to each intermediate variable, and the other is to analyze the smoothness of transmission from each intermediate variable to the final target variable. At the first level, each channel is examined first, and the explanatory variable is the policy interest rate in Denmark, with the overnight interest rate as the proxy variable, which is denoted as RATE in this paper; the policy transmission variables are examined in the credit channel with the amount of bank loans, the asset price channel with the price changes of stocks and real estate, the wealth channel with the changes of consumption, and the exchange rate channel with the changes of exchange rate directly. Therefore, the intermediate variables selected in this paper include bank sector credit (excluding government sector credit and taking the natural logarithm) (denoted as LNLOAN in this paper); the logarithmic return on the monthly closing price of the Danish C20 index (denoted as SPI in this paper); the Danish house price index (denoted as RPI in this paper); the Danish consumption index (denoted as CS in this paper); and the exchange rate under the direct markup of the Danish krone to the U.S. dollar (denoted as EX). At the second level, with each policy transmission variable as the explanatory variable and the Danish final target variables as the explained variables, this paper examines the impact of NIRP on output growth and price stability. In this paper, the industrial production index and the core consumer price index are used as proxy variables for economic growth and inflation, respectively, and are denoted as IP and HICP. In terms of indicator treatment, monthly data are used as the basis of the model, and as for indicators which only quarterly data are published, the Quadratic-match average/sum method is used to convert them to monthly data, and as for indicators which only daily data are published high-frequency indicators, we use the indicators of month-end. In addition, the bank loans and total consumer goods are logarithmic, and the logarithmic returns of stock price indices are chosen. The data are obtained from WIND software, Eurostat and the Danish Stock Exchange website.

In the model selection, considering that the impact of monetary policy on the market is often influenced by pro-cyclicality and other factors, and has different performance in different periods, along with the passage of time, monetary authorities gradually weaken the administrative intervention of monetary policy regulation, the money supply process shows a gradually enhanced output gap-driven characteristics. The VAR model with time-varying parameters can estimate the time-varying parameters, and the TVP-SV-VAR model can well depict the time-varying characteristics of the monetary transmission mechanism. Therefore, this paper argues that the time-varying characteristics of NIRP should be considered in the study of their policy effects, and the TVP-SV-VAR model should be used as the basic tool in the research methodology.

Table 2: List of indicators of the Danish model

Nature of Indicators	Indicator content	Abbreviations
Policy Tools	Overnight Rate	RATE
Policy Transmission Indicators	Natural logarithm of credit in the banking sector	LNLOAN
	Log returns of the Danish C20 index	DLNSPI
	Danish House Price Index	RPI
	Danish Consumer Index	CS
	US Dollar to Danish Krone Exchange Rate	EX
Final target Indicators	Industrial Production Index	IP
	Core Consumer Price Index	HICP

5. Model Analysis of Denmark's NIRP

The Danish central bank started to implement the NIRP in July 2012, so this paper intends to use monthly data from July 2011 to June 2021, that is from one year before the implementation of the NIRP to the present, in order to analyze the impact of the NIRP at three different points in time: before, at the time of, and after the implementation of the policy.

Since the regression of non-stationary series may cause "pseudo-regression", the smoothness of the TVP-SV-VAR data is required, so the smoothness of each time series should be tested first. In this paper, the ADF unit root test is used, and the variables are found to be single integer of order 1 after the test. As for the lags, judging from the AIC principle of model lag order, the lags order of the model are chosen to be 1st order lag.

In terms of convergence, the Geweke values (CD statistics) of the parameters do not exceed the 5% threshold. As far as the inefficiency factors are concerned, under the condition of a certain number of simulations, the less the null factor is, the more reasonable the estimation results are. The estimation results show that the null hypothesis of convergence to the posterior distribution cannot be rejected. Also the maximum value of the null factor in the results is 184.33, indicating that 10000/184.33, or 54 uncorrelated samples, can be obtained with 10,000 samples, indicating that the estimation using the MCMC algorithm is valid and can support the posterior inference of the TVP-SV-VAR model.

5.1. Empirical Analysis of Nominal NIRP on Policy Transmission Variables

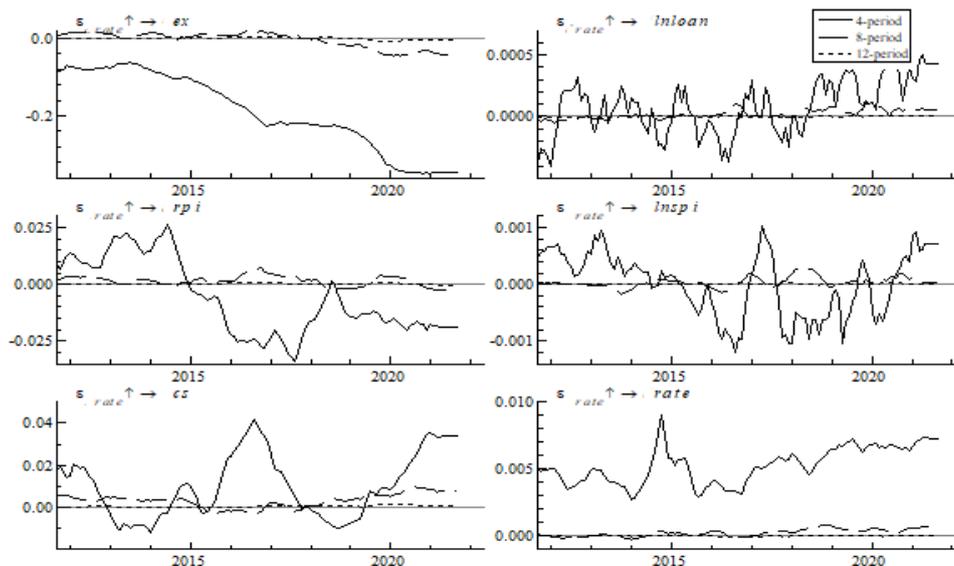


Figure 1: Impulse responses of the Danish NIRP for different lags of the policy transmission variable

Figure 1 shows the impulse response function for equal time intervals in Denmark. In this paper, the impulse response durations of 4, 8 and 12 periods are all chosen to represent the short-, medium- and long-term impacts. The black solid line in the figure indicates a 4-period lag, the long dashed line

indicates an 8-period lag, and the short dashed line indicates a 12-period lag. As can be seen in Figure 1, the impulse response at lag 4 is larger than the impulse responses at lags 8 and 12, indicating that the short-term effects of the intermediate variables of monetary policy are larger.

The first column of the first row of Figure 1 reflects the impulse responses of interest rates on exchange rates at different lags. In terms of the short-term effects of interest rates on exchange rates, the effects are basically negative and do not have obvious time-varying characteristics, and the linkage between the two is relatively stable, with a shock change of -0.06% when the NIRP was implemented in 2012. In the short term, a fall in interest rates leads to a rise in the exchange rate and accelerates the depreciation of the local currency. In the medium and long term, the impact has a clear time-varying character. As seen in the figure, with the sharp decline in the Danish policy rate in 2015, the number of negative values of the lagged response of the exchange rate to interest rate shocks has been increasing, forming an extreme value in 2019.

As seen in the second column of the first row of Figure 1, the impulse responses of interest rates to credit at different lags have significant time-varying characteristics, with NIRP having a more pronounced negative impact on credit at the beginning of its implementation, reaching a trough in 2012 with a shock change of -0.004%. Afterwards, it rapidly rises and oscillates around zero. Comparing to Figure 2 Danish corporate credit graph, it can be seen that there is an inflection point in Danish corporate credit after 2009, and the rising trend changes to a slow decline, with a small rise in 2012 after the implementation of NIRP in Denmark, which lasts for a few months and then continues downward until 2013 when credit starts to bottom out and then starts a slow rise. Table 2 shows that exports recovered to pre-crisis levels in 2011, while imports did not return to 2008 levels until around 2014, and domestic household consumption showed low confidence and slow recovery, with insufficient domestic demand being an important factor inhibiting business investment. Thus, despite the lower interest rates, the stimulus to credit has been limited.

Table 2: Comparison of credit, consumption, imports and exports of Danish enterprises

time	Corporate Credit	Average household consumption	Export	Import
2007	10866502	350367	75,280.00	71,526.30
2008	12454236.4	340824	79,495.90	74,355.60
2009	12776258.8	316161	67,381.70	59,602.10
2010	12732792.8	325968	72,746.70	62,647.80
2011	12445001.1	320986	80,362.10	68,723.60
2012	12289834.5	314891	83,336.30	71,453.70
2013	12045781.3	313597	83,539.40	73,298.80
2014	12127750.6	312190	83,911.70	74,970.70
2015	12273137	308583	86,060.30	77,173.20
2016	12525852.4	298823	86,136.70	77,292.10

Note: Corporate credit in million DKK, average household consumption in DKK (in real prices), exports and imports in million EUR

The first column of the second row of Figure 1 represents the results of the equally spaced impulse responses of interest rates on the real estate market, which shows that there is a significant lag and time-varying impact of interest rates on the real estate price index. In the short term, in 2012, along with the decline in interest rates to negative values, real estate market prices continued to fall due to the late impact of the financial crisis, with a NIRP shock change of 0.015%. In 2015, the Danish central bank lowered the benchmark interest rate to -0.75%, and the impulse response results turned from positive to negative, and then remained in the negative region, and the deepening of the NIRP made house prices rise. The impulse response formed an extreme value in 2018, and a large amount of international capital poured into the Danish real estate market, driving further strength in Danish house prices. The figure shows that the medium- to long-term impact of interest rates on the real estate price index fluctuates around the zero value with limited effect.

The second column of the second row of Figure 1 reflects the impulse response of interest rates to the stock market at different lags. Similar to the response of the real estate market, the impulse response of interest rate shocks to the stock market has time-varying characteristics, with a positive relationship between the NIRP and the stock market in 2012, with a variation of 0.0006%. The decline in the Danish stock market is mainly due to the negative factors such as the European debt crisis and the downgrade of the U.S. sovereign credit rating. The impulse response of the stock market turns to a negative correlation after 2015, when the decline in interest rates drives up stock market prices, and then remains largely in

the negative region. In the long run, the value of the impulse response of interest rates on the stock market is almost zero and has very little impact.

The first column of the third row of Figure 1 shows the impulse response of interest rates on consumption. When the NIRP was implemented in Denmark in 2012, the graph shows that the positive lagged response of interest rates to consumption shocks declined gradually from an extreme value of 0.01% after the implementation of the NIRP, turned negative in 2013, and turned negative in 2014 after the Danish central bank withdrew from the NIRP. The negative response disappears in 2014 when the Danish central bank withdraws from the NIRP and again turns into a positive impulse response. This is mainly due to the lack of consumer confidence in the future economy and weak consumption growth due to the European debt crisis, Figure 2 shows that since the outbreak of the European debt crisis, the Danish consumer confidence index has continued to remain at a low level, and after the European debt crisis spread from Greece to five countries such as Spain and Italy in 2011, the Danish consumer confidence index fell sharply to negative values, which led to a lack of domestic demand in Denmark. 2013, as the various stimulus policies under the euro zone out of the crisis, the Danish economy began to recover, Danish consumer confidence rose sharply and consumption turned to negative impulse response under the NIRP. Therefore, the impact of NIRP on consumption has a lag.

Taken together, the NIRP in Denmark has the most stable and largest impact on the exchange rate and has a pulling effect on domestic credit, but the effect is very short-lived. Asset prices and consumption, on the other hand, are subject to other influences and the effect is not significant. Given that the objective of the Danish central bank's NIRP is to ease the pressure on the appreciation of the Danish krone, in this sense, the Danish NIRP has achieved its monetary policy objective.

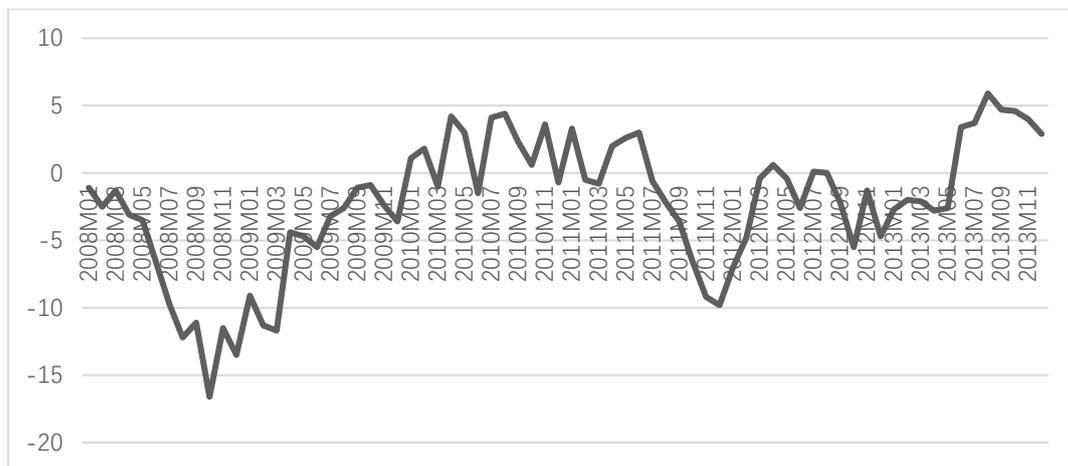


Figure 2: Graph of Danish consumer confidence

Figure 3 shows the time-point-specific impulse results of the TVP-SV-VAR model. As seen in Figure 3, the responses of each intermediate variable to the NIRP have significant lags, and almost all of them do not respond in the current period.

The first column of the first row indicates the results of the impulse response of interest rates to the exchange rate. The responses to shocks at the three different time points are essentially the same and perform more consistently. The impulse response of the exchange rate is mostly in the negative region, reaching an extreme value of -0.5% in period 3 and then converging to a level close to zero in period 8. The second column of the first row indicates the results of the impulse response of interest rates to credit. As seen in the figure, the impulse response of credit to interest rates differs at the three time points. the impulse response of credit in July 2012 is more moderate compared to the response in August 2015 and February 2018. The impulse responses at all three different points in time reach a maximum in period 2 and then fall rapidly to negative values. As analyzed earlier, despite the NIRP implemented by the Danish central bank in 2012, which drove down the cost of borrowing for firms, credit growth was underdriven by increased export risk due to insufficient domestic demand and sluggish economies of external trading partners.

The first column of the second row and the first column of the third row show the impulse response plots of interest rates on house prices and consumption at different points in time, respectively. The two impulse response plots are very similar in that both reach a positive maximum in the second period and then alternate between positive and negative. The impulse responses for the three different points in time

for house prices converge after period 6, while the impulse response for consumption converges to zero value after period 8. The real estate market is more susceptible to policy influence and its movements are influenced by intricate factors; therefore, the interest rate is not robust to the real estate market. Consumption, on the other hand, is not only affected by variable factors such as interest rates, but consumers' expectations about the future also play a non-negligible role. Under the European debt crisis, Danish consumers are not optimistic about future expectations, and even if the opportunity cost of consumption decreases, consumers will still be cautious about consumption, so the impulse response is positive in period 1 before turning to a negative shock in period 2.

The second column of the second row represents the impulse response plot of interest rates on the stock market. The impulse response trends at the three different time points are basically similar, all alternating positive and negative, with unstable results. The magnitude of the shock to the stock market in August 2015 is larger than that in July 2012 and February 2018, and then slowly increases, with the impulse response to the stock market in July 2012 converging after returning to a positive value in period 4. The impact on the stock market of two separate negative interest rate hikes from -0.05% to -0.75% by the Danish Central Bank in 2015 is larger than that of the NIRP in 2012, when the NIRP was implemented.

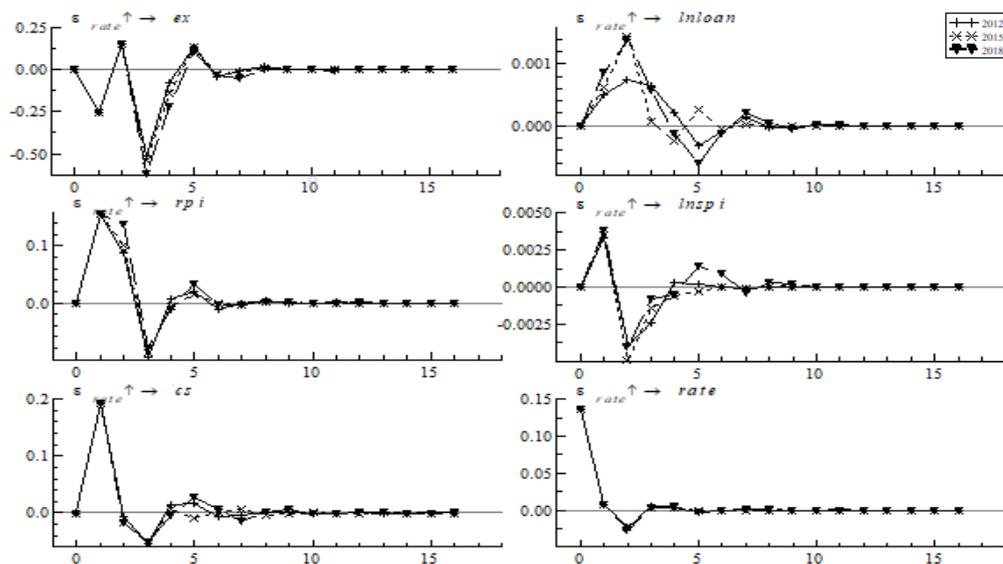


Figure 3: Impulse responses of the Danish NIRP on policy transmission variables at different points in time

In summary, the NIRP in Denmark has the most stable and significant effect on the exchange rate and the less stable effect on the other variables. The impacts of NIRP on credit, real estate market and stock market at the beginning of the policy are less positive than those when the policy is strengthened in depth later. The impact of NIRP on credit and consumption is more volatile.

5.2. Empirical analysis of the policy transmission variable NIRP

The first column in Figures 4 and 6 shows the impulse responses of each transmission variable for different lags on the final variable, ip, and the second column shows the impulse responses of each transmission variable for different lags on the final variable, hicp, where the solid line indicates a lag of 4 periods, the long dashed line indicates a lag of 8 periods, and the short dashed line indicates a lag of 12 periods. As can be seen in Figure 4, the short-term effects are more pronounced, while the medium- and long-term effects are negligible.

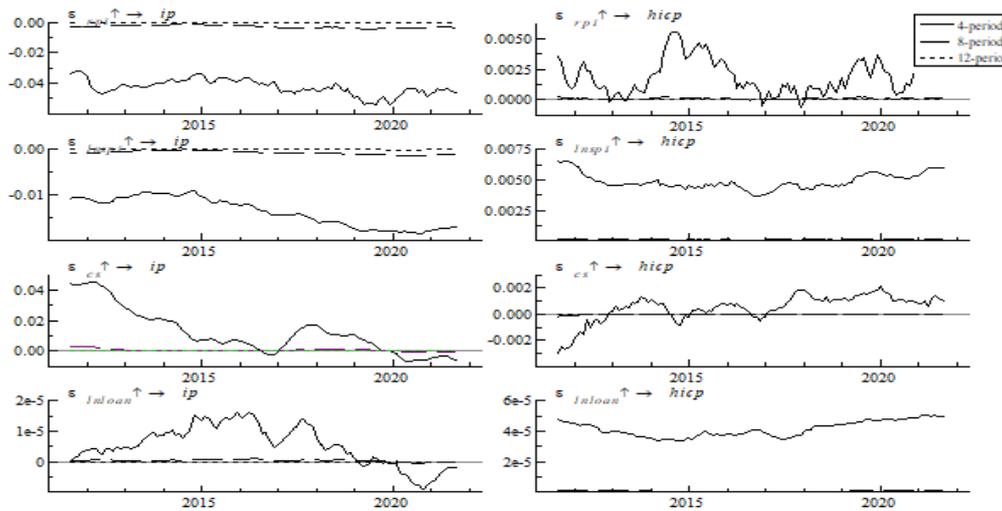


Figure 4: Impulse responses of Danish policy transmission variables with different lags to the final monetary policy target

As can be seen in the first column I and II of Figure 4, economic growth shocks to the real estate and stock markets exhibit non-time-varying stable negative impulse responses in the short run, the impulse response of which strengthens to a phase extreme, then begin to diminish in 2012, with shocks varying by -0.05% and -0.01%, respectively. The impulse responses form a pole in 2019 when the policy rate remains low again. As can be seen from Figure 2, the impact of the NIRP on the real estate market and the stock market is small, positive at the beginning of implementation, and only turns into a negative shock after the deepening of the NIRP in 2015, meanwhile, as it attracts a large amount of safe-haven funds to the Danish real estate market and stock market, further pushing up the development of prices in both markets, this part of the funds does not effectively play a wealth effect, so the role played by the Danish asset price transmission channel is limited.

The graph in the third row of the first column shows that the lagged response of economic growth to consumption shocks remains mainly in the positive region, i.e., economic growth holds an upward trend as consumption increases. The figure shows the largest impulse response in the current period, with a shock variation of 0.04%, then gradually decreases, and develop shockily after the bottom in 2015. The impact of consumption on economic growth during the European debt crisis is significant, and then begins to decline. NIRP makes consumption grow in 2013, when the impulse response of economic growth stops falling and rebounding slightly and then continues smoothly until 2014 when Denmark temporarily withdraws from the NIRP, and in 2015 Denmark lowers the NIRP to -0.75%, and the impulse response of economic growth also forms phase extremes.

The fourth row of the graph in the first column represents the impulse response of economic growth to credit shocks with different lags. Unlike asset prices and consumption, credit has a significant lag to economic growth and the positive shock to economic growth reaches its maximum in 2015 and converges towards zero after 2019. As can be seen in Figure 5, the year-over-year trend of Danish GDP shows that the Danish economy was negatively affected by the European debt crisis in 2010 and its growth rate declined, stabilized upward after 2012, and slowed down after peaking in 2016, with a trend broadly consistent with the impulse response in Figure 4.

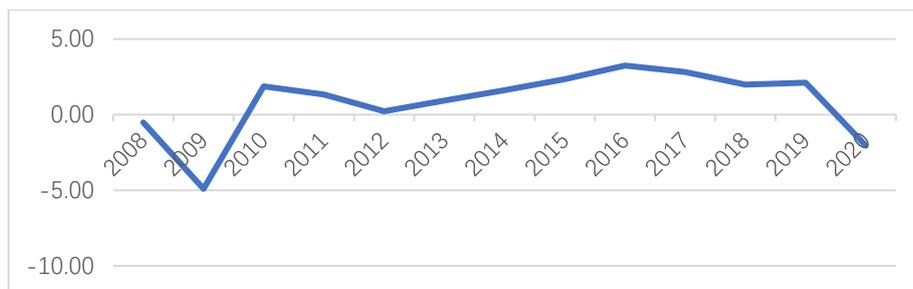


Figure 5: Denmark GDP year-over-year trend

The graphs in the second column I, II and IV of Figure 4 show that inflation shocks to house prices,

stock indices and credit exhibit non-time-varying and all have a relatively stable positive relationship, i.e., rising house prices, stock indices and credit lead to higher inflation. The impulse response of inflation to stock index and credit shocks forms a wave in the current period, reaches a maximum, and then plateaus. The value of inflation impulse response to house price shocks shows a downward trend in 2013, but starts to rise in 2013 and reaches a maximum in mid-2014, forming a wave, and then oscillates downward and tends to converge, with the impact tending to become larger in 2019 and the effect continuing and tending to strengthen after 2021. The third row of the graph in the second column shows that there is a lag in the impulse response of inflation to consumption shocks, with a largely positive correlation in 2013.

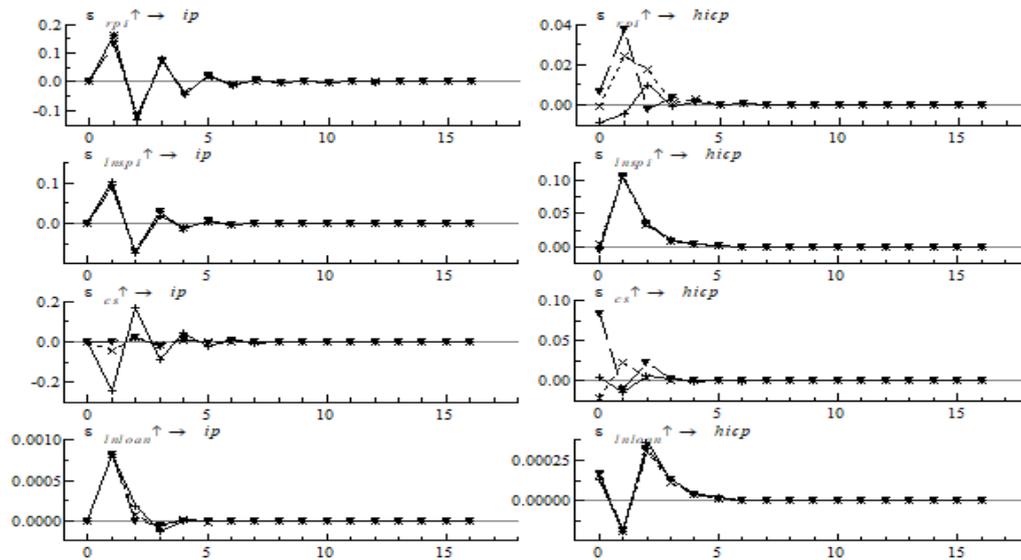


Figure 6: Impulse responses of policy transmission variables to different points in time of the final monetary policy target

Figure 6 shows the impulse results at specific points in time, where the first column, first and second rows indicate the impulse response results of economic growth to house price and stock index shocks. The impulse responses at the three different time points are basically the same, and the impulse response values have obvious time-varying and lagging characteristics, and converge after period 5. The third row of the first column indicates the impulse response results of economic growth to consumption shocks. As seen in the figure, in comparison, the impulse response of consumption performs most dramatically in July 2012, This shows that the impact of consumption on economic growth has a clear time-varying character, with the largest impact of consumption on economic growth at the beginning of the implementation of the NIRP, which supports the change in the impulse response in Figure 4. The fourth row of the first column reflects the results of the impulse responses of economic growth to credit shocks. The figure shows that the impulse response declines rapidly, with the effect going to almost zero after only 2 periods.

The first row of the second column represents the impulse response plot for the real estate market on inflation. The impulse responses of July 2012 only change from negative to positive in the middle of period 1, reaching a maximum in period 2, but its intensity is significantly smaller than the impulse responses of the other two time points, which converge in period 3. The second row of the second column shows the impulse responses of the stock market to inflation of all three different time points have obvious lags and strong stability, and do not have time-varying characteristics. The impulse responses of inflation on consumption shocks at different points in the third row of the second column can be seen in the graph of the impulse responses of the three different points in the first three periods show large variability. The impulse response value in July 2012 falls in period 2 to a negative value and then rapidly goes to zero. The impulse response plot for inflation on credit shocks at different time points in the fourth row of the second column shows that the impulse responses at the three different time points have time-varying characteristics, oscillating between positive and negative values after being positive in the current period, and converging after the effect persists until period 5.

Combining these plots, it can be seen that the Danish NIRP has the most significant effect on the exchange rate, while the effects on other variables are less stable. The effects of NIRP on credit, real

estate market and stock market at the beginning of the policy are less than those brought by the deeper policy in the later period. The impact of NIRP on credit and consumption is more volatile. In Denmark, the exchange rate channel of the NIRP is open, while the asset price channel has a limited role, credit is limited by the lack of market demand and is more volatile, and although credit has a positive effect on economic growth, the effect is very limited and the interest rate channel is not open enough. Consumption has a strong influence on economic growth, especially in the time of European debt crisis, limited by the lack of market confidence, the effect of NIRP on consumption is limited, and thus the wealth channel smoothness is also insufficient.

6. Main conclusions and recommendations

This paper empirically analyzes the transmission and effects of NIRP in Denmark through the TVP-SV-VAR model. The results show that, first, the exchange rate channel of NIRP in Denmark is open, and the NIRP depreciates the Danish krone, thus increasing exports and effectively promoting economic growth. Second, the interest rate channel in Denmark plays a limited role, as NIRP stimulate the economy and inflation through credit, but are susceptible to a combination of factors that have short-term effects on credit, thus affecting the ultimate objective. Third, the Danish wealth channel is not sufficiently open and micro-behavioral consumption is affected by market confidence and other factors with lagged effects. Despite the strong impact on economic growth, the impulse response of NIRP on consumption is unstable, making the role of consumption on economic growth decline rapidly and the impact on inflation unstable. Third, the Danish capital and real estate markets were affected by the European debt crisis, etc., and did not show a positive response at the beginning of the NIRP, and only turned positive after the central bank increased the policy, but due to its openness, foreign capital was attracted to the capital and real estate markets, which was effective in stimulating inflation but did not play a stimulating role in economic growth. Therefore, the asset portfolio channel for implementing NIRP is not open. Since the purpose of the NIRP in Denmark is to relieve the pressure of exchange rate appreciation, the NIRP in Denmark is effective from this perspective.

The study on the transmission effects of NIRP in Denmark can bring us the following insights.

First, monetary policy is not absolutely effective in promoting economic growth and achieving inflation targets, and many factors can affect the transmission effect and policy effect of monetary policy. Denmark's NIRP has not been effective in stimulating the growth of bank credit and consumption, and the lack of consumer confidence has led to slow growth in consumption and investment, thus reducing the smoothness of the interest rate channel and wealth channel. Therefore, when implementing monetary policy in China, we need to pay attention to expectations management, and the central bank should strengthen monetary policy communication and forward guidance with financial institutions and related parties to guide market expectations and effectively improve the transparency of monetary policy, thus contributing to the smoothness of monetary policy channels.

Second, Denmark's economy recovered quickly from the crisis thanks to an active industrial policy. In addition to traditional agricultural and fishery products, Denmark's pillar industries, the pharmaceutical industry and energy-saving and environmental protection industry also have strong market competitiveness, so the objective of Denmark's NIRP is only set to resolve the excessive appreciation of the local currency. An important reason why Denmark's NIRP is considered the most successful is that it does not rely on monetary policy alone to stimulate the economy. Therefore, for China, to promote economic growth must monetary policy must be used in combination with industrial policy and fiscal policy, deepen supply-side reform, and steadily achieve technological innovation and industrial upgrading in order to effectively achieve steady economic growth.

Third, the opening of the capital market and real estate market needs to be treated with caution. The opening of the Danish capital market and real estate market has enabled international hedge funds to enter the Danish market quickly and at low cost, which not only caused greater appreciation pressure on the Danish krone, but also pushed up the prices of the two markets. The previous empirical evidence shows that the asset price channel and wealth channel did not lead to the growth of consumption and credit, but led to the creation of market bubbles. Therefore, the opening of China's capital market and real estate market should follow the principle of steady and orderly progress, consolidate the relevant mechanisms and institutions, strengthen the stability of the financial system, and improve the ability to cope with international capital shocks.

Fourth, the prudent use of unconventional monetary policy. The effect of NIRP is limited, but it may have a series of negative effects such as lack of confidence in the market due to aggressive policies. After

the financial crisis, financial fragility has increased, and the COVID-19 pandemic continues to have a huge impact on the global economy. How to adjust monetary policy so that it can play a greater role in the new economic environment and make the monetary policy channel more smooth is a major task for Chinese financial authorities to tackle under the new situation. In mid 2013, China made the official launch of unconventional monetary policies such as medium-term lending facilities and targeted downgrades, which are more targeted as the innovation of monetary policy tools being trimming and directional control. NIRP in the name of this kind of "water flood irrigation" type of regulation may lead to structural problem become more prominent, therefore China should be careful to use NIRP as a monetary policy target.

References

- [1] Irving Fisher (1930). *The Theory of Interest*. New York: MacMillan, 578-724.
- [2] Marvin Goodfriend (2000). *Overcoming the Zero Bound on Interest Rate Policy*. *Journal of Money, Credit and Banking*, 32(4), 1007-1035.
- [3] Willem H Buiter; Panigirtzoglou N (2003). *Overcoming the Zero Bound on Nominal Interest Rates with the Negative Interest on Currency: Gesell's Solution*. *The Economic Journal*, , (10): 723-746.
- [4] Madaschi Christophe, Pablos Nuevo Irene (2017). *The Profitability of Banks in a Context of Negative Monetary Policy Rates: the Cases of Sweden and Denmark*. *European Central Bank Occasional Paper NO.195* .
- [5] Khayat G A (2017). *The impact of setting negative policy rates on banking flows and exchange rates* [J]. *Economic Modelling*, , (68), 1-10.
- [6] Sun GuoFeng, He Xiaobei (2017). *Zero lower bound on deposit rate and negative interest rate transmission mechanism*. *Economic Research*, 12, 105-117.
- [7] Wang ChangYuan, Zhang HongYu (2019). *The logic, policy framework and practice of implementing NIRP by central banks*. *Shanghai Finance*, (9), 32-38.
- [8] Li Jie, Hou HongChang, Li BoNan. *The impact of interest rate on private saving - A study based on negative interest rate environment*. *Journal of Central University of Finance and Economics*. 1, 97-107.
- [9] Marco Bassetto. NIRP (2004). *American Economic Review*, 94(2), 104-108.
- [10] Gnan E, Beer C (2015). *Asset-liability management with ultra-low interest rates*. *The European Money and Finance Forum, Vienna SUERF Studies*, 2015 /2, .
- [11] Palley T I (2016). *Why ZLB economics and Negative Interest Rate Policy (NIRP) are wrong: A theoretical critique*. *IMK Working Paper No.172* .
- [12] Siegel Laurence B, Sexauer Stephen C (2017). *Five Mysteries Surrounding Low and Negative Interest Rates*. *The Journal of Portfolio Management*, , 43(3), 77-86.
- [13] Agarwal R, Kimball M (2015). *Breaking through the Zero Lower Bound*. *IMF Working Paper, NO. 2015/224*.
- [14] Hannoun H (2015). *The impact of ultra low or negative interest rates on financial stability and economic growth*. *Modern Bankers*, 6, 142-146.
- [15] Stiglitz J E (2016). *What's Wrong with Negative Rates?* <https://cgt.columbia.edu/news/stiglitz-whats-wrong-negative-rates>, .
- [16] Zeng Zhi, He Yating, Cao Guohua (2017). *A study of negative interest rates, bank risk-taking and risk heterogeneity-an empirical analysis based on the European banking sector*. *Business Research*. ,7, 44-51.
- [17] Lu Chao, Sun Yajing, Du Jia (2019). *Assessment of the effect of NIRP implementation in Europe and outlook-a study based on synthetic control method*. *Contemporary Finance and Economics*., 1, 60-72.
- [18] Xiong Qiyue, Wang Shujiao (2020). *A study on the mechanism of negative interest rate impact on banks' net interest margin-empirical evidence based on major listed banks in Europe*. *Financial Research*, 1, 110-129.