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Faculty of Social Sciences
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BACHELOR'S THESIS

**How Can the Czech National Bank
Eliminate the Zero Lower Bound on
Interest Rates? A Case Study**

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, May 2, 2018

Signature

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Abstract

The thesis provides case study research on the feasibility of the negative interest rate policy in the context of the Czech Republic. No major obstacles opposing the policy itself were found in the bases of the Czech legal system, however, a list of acts explicitly affected by the value of policy rates needs to be adjusted to prevent misinterpretations. Moreover, it was identified that tax prepayments held by the Tax Authority and free reserves kept at the Czech National Bank at zero interest rate create room for escaping from the policy. Additionally, debt repayments in cash and interest-free accounts of government and public institutions administrated by the Czech National Bank could lead to undesirable advantages. A complementary VAR model analysis of the interest rate transmission under negative policy rates was performed to evaluate quantitatively the experience from European countries, however, short data series available provided merely indicative results.

JEL Classification E42, E44, E52, E58, C32

Keywords zero lower bound, negative interest rates, the Czech National Bank, case study research, vector autoregression

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Abstrakt

Táto bakalárska práca spracováva prípadovú štúdiu uskutočniteľnosti zavedenia monetárnej politiky záporných úrokových sadzieb v Českej republike. Vo všeobecnosti neboli nájdené žiadne výrazné prekážky v použití záporných úrokových sadzieb. Niekoľko zákonov by si však vyžadovalo novelizáciu s cieľom zabrániť nesprávnej interpretácii. Taktiež bolo identifikované, že zálohy na daň z príjmu platené Finančnej správe a voľné rezervy komerčných bánk uložené v Českej národnej banke predstavujú možnosti úniku pred účinnosťou tejto monetárnej politiky. Splácanie dlhu v hotovosti a garantované úročenie nulovou úrokovou sadzbou na účtoch štátnej pokladnice vedené Českou národnou bankou by tiež mohli viesť k neželaným, prípadne nezákonným výhodám pre niektorú zo strán. Doplňujúca analýza menovej transmisie v prostredí záporných úrokových sadzieb pomocou VAR modelu ponúka kvantitatívne zhodnotenie skúseností s politikou záporných sadzieb v Európe. Krátky časový rad ale dáva možnosť prezentovať len predbežné výsledky.

Klasifikace JEL

E42, E44, E52, E58, C32

Klíčová slova

nulová dolná hranica, záporné úrokové sadzby, Česká Národní Banka, prípadová štúdia, vektorová autoregresia

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Acronyms

NIRP	Negative Interest Rate Policy
ZLB	Zero Lower Bound
ELB	Effective Lower Bound
CNB	Czech National Bank
ECB	European Central Bank
QE	Quantitative Easing
VAR	Vector Autoregression
GDP	Gross Domestic Product
HICP	Harmonised Index of Consumer Prices
IR	Interest rate
ADF	Augmented Dicky-Fuller
PP	Phillips-Perron Unit Root
IMF	International Monetary Fund
PCIR	Paper Currency Exchange Rate
CSR	Case Study Research
POS	Point of Sales

Bachelor's Thesis Proposal

Author	Alexandra Katinová
Supervisor	doc. PhDr. Tomáš Havránek, Ph.D.
Proposed topic	How Can the Czech National Bank Eliminate the Zero Lower Bound on Interest Rates? A Case Study

Motivation After the financial crisis of 2008-2009, we could observe conventional monetary policies failing to satisfy the expectations about growth and quick economic recovery. Therefore, different forms of unconventional monetary policies started to be discussed more often, allowing interest rates to decrease into negative territory as one of the alternatives. Still today, the European economy is dealing with poorly performing growth and depressed inflation expectations which invites a rethink of the monetary policy strategies and preparation of potential tools to face another crisis that could appear sooner or later.

Eliminating the zero lower bound (ZLB) on the cash desks of central banks (CB) seems to be a policy that could work in case of the next recession. That is why we need to be aware of all necessities related to its implementation. The International Monetary Fund published a working paper, *Breaking through the zero lower bound* by Agarwal & Kimball (2015), treating the issues related to the introduction of a paper currency deposit fee at the cash desks of CB to eliminate the ZLB. In my thesis, I will focus on applying this study to the Czech environment, practically, discussing the technical as well as legal aspects of the proposed system. This way, a feasibility study of introducing new tools by the Czech National Bank (CNB) to make negative interest rates effective would be created showing whether this instrument is ready to be considered in the Czech Republic and if so, what are the necessary steps to be taken.

Furthermore, there have been numerous debates over the pass-through of these negative rates to the market. Literature provided by Swedish and Danish Central Banks as well as the ECB shows conclusions about the phenomenon. However, to the best of my knowledge, substantial analysis is missing. Thus, VAR analysis of the

pass-through of the Central Banks' rates will be added to the thesis, inspecting the difference between pass-through in the period of positive rates compared to the recent period of negative rates in 5 economies that have already adopted this unconventional monetary policy (Sweden, Denmark, Switzerland, ECB and Hungary)

The main questions of the thesis would be: How Can the Czech National Bank Eliminate the Zero Lower Bound of Interest Rates? Is it technically and legally possible to eliminate the zero lower bound of interest rates at the cash desk of CNB in accordance with the paper proposed by Kimball and Agarwal? What are the potential problems? Once the system is implemented, can we expect an effective transmission? (Evidence from countries, which already adopted negative rates using VAR analysis)

Expected Contribution Even though the topic of negative interest rates is frequently discussed these days, the practical structure of implementation has not yet been elaborated for individual European countries, the Czech Republic not excluded. This thesis should, therefore, work on revealing possibilities how the zero lower bound can be eliminated by the CNB, thus providing framework of important issues to consider while implementing this unconventional monetary policy in the future.

Methodology For the first part, the most relevant approach is empirical (case study), pointing to steps and problems that may arise during implementation in the Czech environment. For the second part, I am going to conduct a macroeconometric method - Vector Autoregression (VAR) analysis to study interest rate transmission in countries having already adopted negative interest rates. For VAR analysis, I am going to use time-series data of interest rates in specific countries:

Sweden (<http://www.riksbank.se>)

Denmark (<http://nationalbanken.statbank.dk>)

Switzerland (www.snb.ch)

ECB (<http://sdw.ecb.europa.eu>)

Hungary (<https://www.mnb.hu/en/statistics>)

Furthermore, data from Eurostat or additional databases of macroeconomic data will be used.

Outline

1. Introduction
2. Negative Interest Rates as an unconventional monetary policy
3. Theoretical proposition of IMF

4. Case study - Application of the proposition to the Czech environment
5. VAR analysis - difference in pass-through of the rates between periods of positive and negative rates (evidence from specific countries)
6. Conclusion

Core bibliography

Ruchir Agarwal and Miles Kimball, (2015), Breaking Through the Zero Lower Bound, IMF Working Papers (WP/15/224)

Andreas Jobst and Huidan Lin, (2016), Negative Interest Rate Policy (NIRP): Implications for Monetary Transmission and Bank Profitability in the Euro Area, IMF Working Papers (WP/16/172)

Morten Bech and Aytek Malkhozov, (2016), How have central banks implemented negative policy rates? BIS Quarterly Review, March 2016

Wolfgang Lemke, Andreea Liliana Vladu, (2017), Below the zero lower bound: a shadow-rate term structure model for the euro area, ECB Working Papers, No 1991

Laurence Ball, Joseph Gagnon, Patrick Honohan and Signe Krogstrup, (2016), What else can Central Banks do?, International Centre for Monetary and Banking Studies

Gert Peersman and Frank Smets, (2001), The monetary transmission mechanism in the Euro Area: More evidence from VAR analysis, ECB Working Paper Series, Working Paper n.91

Official Journal of the European Union, L 94/75, (2009), REGULATION (EC) No 290/2009 OF THE EUROPEAN CENTRAL BANK of 31 March 2009

Chapter 1

Introduction

The damage of the latest financial crisis of 2008 called for “never before seen monetary policy measures” (Cœuré 2012). Apart from applying standard actions (interest rate channel, tightening or easing money supply), central banks needed to develop non-standard tools as well (Negative Interest Rate Policy (NIRP), Quantitative Easing (QE), Currency Interventions) in hope of tackling the recession and the subsequent era of low interest rates and low inflation. Looking forward, non-standard measures will continue to be used as: (i) the period of low interest rates is expected to last (assuming no major structural reforms are introduced, influencing demographic trends and consumer behaviour globally (Rachel & Smith 2017)); and (ii) monetary policies are argued to be limited by the zero lower bound on interest rates (Kiley & Roberts 2017; Rachel & Smith 2017).

These claims require substantial attention of policy makers and highlight the necessity to prepare for the next crisis, as it is very likely that lowering policy rates to zero will not be sufficient response to destabilised economic conditions in the next recession. Central bankers should, therefore, choose a policy well in advance in order to be ready in time to manage the fluctuations of the business cycle under low interest rates conditions. From several possible measures, breaking the lower bound on interest rates and introducing the NIRP are frequently cited procedures in the literature and seem to become essential challenges to be faced in order to equip central banks with the possibility to lower policy rates (deep) into negative territory and keep the interest rate channel of monetary policy functional in a future fight against economic downturn.

NIRP could encourage the spending of economic agents in order to increase aggregate demand, which is depressed during a recession. The economic theory suggests that one way to stimulate spending is to decrease the interest rates earned by savers, thus lowering opportunity costs of investments. The interest rate channel of the monetary policy is an asymmetric tool that can be increased indefinitely on one hand, on the other hand, its downward movement is limited by zero level (Buiter 2015b). Consequently, in periods of low interest rates this monetary measure will not aid policy makers against the low aggregate demand.

Recently, a few European countries have introduced negative reference rates breaking the dogmatic view on the interest rates as a penalty for debtors and a reward for savers. However, a few questions arise: (i) whether these slight negative interest rates work properly and not under some inefficiencies of zero (effective) lower bound; and (ii) how far the negative rates could go without a structural change to the payment system.

Thus, one of the major obstacles in the function of several monetary policies, including not only negative reference interest rates, but also inflation targeting, may be zero lower bound on interest rates (Rogoff 2017). *Zero Lower Bound (ZLB)* describes the fact that paper currency is issued at zero nominal interest rate and that this state is guaranteed over all circumstances in the future. Therefore, economic rationale suggests that nobody is willing to lend money in the period of negative interest rates, as investment into paper pieces of money would have at least non-negative nominal returns. Additionally, the fact that individuals are aware of the ZLB induces possible ineffectiveness of the policy, as it is expected that rates cannot go deeper into negative territory and the situation is likely to be temporary. These two elements related to the ZLB phenomenon are suggested to prevent efficiency of the negative interest rates.

As suggested before, Europe, and other major economies around the world, encounter problems with long lasting low interest rates. The case of Czech Republic is not different from the rest of the world. The current reference discount rate of the Czech National Bank (CNB) is 0.05% which is considered to be a technical zero level. Nevertheless, further decrease of the rates to stimulate the economy could be needed any time soon. As Franta (2014) presents in his paper released by the CNB, the estimated equilibrium real interest rate for Czech economy is -1.1%. This, together with expectations of very low inflation, could force the Czech economy to implement the negative nominal interest rates. Additionally, Kolcunová (2017) estimates the effective lower bound on interest

rates for Czech economy to be in between -1% and -2 %, further supporting the evidence of urgent need to prepare for negative interest rates introduction. Franta (2014) also notes that the Czech legal system cannot respond correctly to the situation of negative level of interest rates. Consequently, it would be very beneficial to investigate how the CNB could approach the possible monetary measure of decreasing rates below zero level as well as the feasibility of introducing the negative interest rates, either slight or profound, in the Czech environment.

The following work will contribute to the current discussion by providing a practical guide on how to eliminate the ZLB in the environment of the Czech Republic. It will also be the first text enumerating legislative acts expected to cause unintended interpretations related to the NIRP. Due to the alarming need to get prepared for potential upcoming crisis and current very low interest rates, it is extremely important to study further possibilities of a well functioning incorporation of negative interest rates to stimulate demand if necessary. This thesis will be relevant to the recent macroeconomic discussions and will provide a practical approach to the process of monetary policy execution. It will focus not only on summarizing different proposals on establishing negative interest rates through breaking the binding ZLB, but also on the application of the ideas to the specific case of the Czech Republic.

The case study will be performed by reviewing both the legal grounds of the Czech legislation connected to reference rates set by the CNB, as well as the technical side of the potential implementation of the policy. The text should reveal several problems that may be faced by the CNB in the process of establishing the reference rates under zero level. It should also list the necessary steps to be taken to ensure fluent transition to the non-standard form of the policy.

Additionally, as the NIRP is a relatively new approach, opinions on effectiveness of the policy differ. Mishra & Montiel (2012) argue that generally, increase or decrease in policy rates are translated quickly into the interbank rates but they are rather slow when transmitting into the market lending rates. It is, however, still unclear whether this mechanism of transmission of the change in policy rates follows the economic theory under negative interest rates. There are several papers narratively studying the issue of the functionality of the policy and the transmission of negative interest rates into market variables. However, to the best of my knowledge, proper data analysis using frequent macroeconomic methodology - Vector Autoregressive Model - has not yet been

carried out. Therefore, I will investigate the transmission mechanism on available data of countries using this non-standard measure and elaborate a quantitative analysis for each respective country.

First, Denmark has cautiously introduced the latter mentioned unconventional monetary policy in July 2012. The Central Bank of Denmark lowered the Certificate of Deposit rate to -0.2%. Clearly, data availability is very restricted for observing this phenomenon, the longest time series accounting for 66 monthly observations. Therefore, this exercise is merely preliminary, as from the econometric point of view, the limited data availability could result in an underperforming model. A thorough analysis was performed to provide at least some indicative results on the transmission mechanism under the negative interest rate policy, as it is a still very persistent and controversial topic of discussions. While interpreting the results, I will clearly mention the limitations of the model and the results. This exercise is a complementary part of the thesis, indeed, to draw the whole image of the topic, enlarge the contribution of the thesis and add technical value to the bachelor thesis.

The text is organized as follows. After mentioning the most relevant literature sources on the topic in Chapter 2, the methodology and the results of VAR model analysis are presented in Chapter 3. Chapter 4 is devoted to the explanation of the method of eliminating the binding lower bound on interest rates as suggested by economic research. Chapter 5 summarizes the results of the case study investigating the feasibility of the necessary steps for the Czech Republic. The thesis concludes by indicating an action plan for the CNB related to the NIRP introduction and by other remarks.

Chapter 2

Literature Review

The topic of negative interest rates, zero lower bound as well as experience from countries running monetary policies under negative interest rates have been recently substantially discussed in the literature. All relevant sources concerning the mentioned topics will be reviewed in this chapter.

2.1 Negative Interest Rates

The phenomenon of zero and negative interest rates was brought up by Irving Fisher at the end of 19th century in *Appreciation and Interest* (Fisher 1896). It was the pioneering work on the subject and revolutionary in terms of macroeconomic theory, introducing the relationship between nominal and real interest rate. Topics were further developed by Keynes (1936) and interpreted in more details by Hick's (1937). The situation when interest rates hit their lower bound and almost everybody prefers holding cash was named the *liquidity trap*. The idea of negative interest rates and economic thinking about such tool is not new at all. However, it has ceased to be a solely theoretical concept only since the turn of the century. Until now, the interest rates were rarely low enough that economists would even consider negative interest rates, moreover, a convenient alternative form of currency to replace cash has been developed only recently.

A question could be raised why are negative interest rates needed nowadays. The beginning of the 21st century was accompanied by tough times for the financial markets and the world economy. Speculations related to the Dotcom bubble, the real estate market bubble (resulting in the most severe financial crisis of last decades); and the European debt crisis were all significant reasons for the governments and the central banks to search for new approaches to

monetary policies to regain stability and provide additional monetary stimulus to increase demand and promote consumption. The main motivation for the recent applications of the NIRP was to induce and back growth, react to currency appreciation and capital inflows waves, as well as stabilize inflation expectation etc. (Arteta *et al.* 2018).

Why are other policies not more suitable to be used in current macroeconomic monetary policy? Quantitative Easing (QE) is an alternative monetary policy tool that is also considered unconventional and can be used to revive the economy. It has been used by the Bank of Japan, the European Central Bank as well as the Federal Reserve System as a response to the difficulties caused by the financial crisis of 2008, and the consequent low interest rates and low inflation. Several economies using QE claim that this tool is functional. However, the assessments of the policy are not unanimously positive. There have been debates over its efficiency widely, even some negative effects have been suggested. Kumakura (2016) suspects QE to act towards monetizing fiscal debt in Japan and Caldentey (2017) states that the QE employed by various economies in the aftermath of the financial crisis does not contribute to greater financial stability. Rogoff (2017) similarly concludes that QE does not work towards resolving problems caused by interest rates stuck at their lower bound.

Another point, which makes the assessment of the QE unclear is the way the consequences of the policy are measured. It was shown that QE does not affect all financial institutions equally, but its effect is based upon the mortgage-based securities holdings (Rodnyansky & Darmouni 2017). In other words, an important element of the QE transmission is the type of assets that are targeted by the policy. Moreover, it is expected that some economies, mostly smaller ones, would exhaust the bond market quickly, making this policy unsuitable in the general context. The policy is suspected to suffer from imperfections, therefore, from an economic research point of view, it is important to search for more efficient tools.

The European Central Bank (ECB) has been employing two strategies recently, both the NIRP and the QE. It stated the interest rates were pushed down to their effective lower bound (ECB 2014a) and it seems that this channel of monetary policy is exhausted and QE is added to enlarge the monetary stimulus. According to the report, the reasons for the combination of the policies have been to promote lending and provide additional monetary easing to the economy to ensure inflation rates to return to targeted rates below, but close to, 2%. It is argued that QE should be used only after interest rate channel of

monetary policy is used up (Williams 2013; Brunnermeier *et al.* 2017). Having mentioned several disadvantages of QE, breaking through the effective lower bound of interest rates and making deeper negative interest rates applicable seems to be an interesting feature to complete the monetary policy of central banks.

After showing that there is motivation to add negative interest rates into the portfolio of monetary policies for central banks, zero lower bound as an obstacle to the execution of this specific policy will be investigated in more depth.

2.2 Zero Lower Bound

ZLB can be understood as the binding level of the interest rate under which people are not willing to lend money to banks (hold deposits in banks or invest in financial assets). In that situation, they prefer to hold cash, presuming the situation is only temporary. The money supply is increased, but the interest rates cannot drop further down, as they are already reaching their lower bound. This lower bound is the level of interest rate (can be negative), at which the economic agents choose to hold cash instead of bank deposits, as they would earn zero interest rate doing so. This implies that central bank cannot further decrease the interest rate and loses the interest rate channel of the monetary policy. Moreover, if expected inflation is low or negative, Fisher equation suggests negative nominal interest rates are needed even more to restore the economy from the recession. Therefore, the ZLB can be a serious problem in times of depressed demand and very low interest rates. Literature provides research interested in the ZLB of interest rates explaining both the phenomenon and its role in preventing the functionality of the monetary policies.

Buiter & Panigirtzoglou (2003) argue that the notion of *zero lower bound* is also closely related to the phenomenon called the *liquidity trap*, as suggested already by Keynes (1936) and Hick's (1937). They also explain that an economy is in liquidity trap as soon as monetary policy has no power to change real or nominal demand on market. The main reason lies in short nominal interest rates hitting their binding lower level. Furthermore, Buiter & Panigirtzoglou (2003) state that an economy is able to avoid or eliminate the liquidity trap by overcoming the zero lower bound and one of the possible ways to achieve it are negative interest rate payments on base currency.

Many economists reckon the ZLB is a serious problem to a well-functioning

monetary policy (Reifschneider & Williams 1999; Buiter & Panigirtzoglou 2003; Woodford & Eggertsson 2003; Buiter 2009; Agarwal & Kimball 2015). Reifschneider & Williams (1999) concludes that under the Taylor rule and the depressed inflation rates, a monetary policy is constraint by the ZLB. They also state that traditional open-market operations may not provide satisfactory results in guiding the economy out of crises. Woodford & Eggertsson (2003) also adds the welfare dimension to the discussion on the ZLB and concludes that monetary policy is not able to achieve the same level of welfare with a binding ZLB.

On the other hand, Reifschneider & Williams (1999) also admits that periods susceptible to fall into problems with the ZLB are very rare, a general belief at the turn of the milenium, but not evident any more. We see Japan fighting long lasting very low interest rates for the third decade now. Europe and the U.S. deal with low inflation and interest rates as well being unable to create a sufficient monetary stimulus to return to better results. Fischer (2016) noted in his speech, during the Annual Meeting of American Economic Association in 2016, that both length and repetition of periods of low interest rates will be more significant nowadays than in the past and he stressed the need for further research on the topic to eliminate adverse effects of the ZLB.

Recently, more papers appeared, discussing the ZLB constraint (Summers 2014; Williams 2014; Heider *et al.* 2017; Rogoff 2017). Authors all agree the ZLB constitutes a threat to monetary policies, as the interest rate channel is limited by the binding lower level. Baurle & Kaufmann (2014) investigate the Swiss example referring to the ZLB problem in 2013, before introduction of the NIRP by Swiss National Bank. They find out that the reactions of the exchange rate and the price levels to a risk premium shock are greater at the still positive ZLB, making the periods at the ZLB level more volatile and uncertain.

Moreover, this widely accepted concept of the ZLB needs to be reconsidered, as there is growing evidence that the lower constraint is not equal to zero, but slightly less. This phenomenon is related to the cost of holding, transporting and insuring cash. In case of the Czech Republic, Kolcunová (2017) estimates the effective lower bound for Czech Market is in the interval -1% to -2% through two different methods. A similar exercise was performed on the Canadian economy, where the effective lower bound is suggested to be -50 basis points (Witmer & Yang 2016). Even though the estimates of storage and insurance costs are fairly similar in both studies, the estimates of the convenience costs vary substantially. Kolcunová (2017) argues convenience costs of digi-

tal transactions in the Czech market are approximated by 1% of the amount, whereas Witmer & Yang (2016) estimate them at 0% to 0.25% in Canada.

The natural continuation of the topic is to propose a solution to the problem. Most economists interested in the ZLB either suggested ways how to overcome it (Reifschneider & Williams 1999; Buiter & Panigirtzoglou 2003; Woodford & Eggertsson 2003; Buiter 2009; Williams 2014; Agarwal & Kimball 2015; Rogoff 2017) or closely studied the transmission mechanism close to the lower bound (Svensson 2000; Heider *et al.* 2017; Williamson 2017). The two most clearly elaborated proposals on how to solve the puzzle were delivered by Buiter (2009), Agarwal & Kimball (2015) and Rogoff (2017); they will be explained in more depth and details in Chapter 4.

2.3 Recent Experience from European Countries

Year 2014 was a turning point, when reference rates were pushed below zero. Since then, both policy makers and researchers have been interested in early assessment of the new monetary policy tool adopted by 4 major economies in Europe: Denmark, Switzerland, Sweden and the Euro Area. Japan, Norway and Hungary also incorporated the policy into their strategies. However, they only applied negative rates on deposited excess reserves (Jobst & Lin 2016). The focus is therefore put on former 4 countries that lowered their main policy rates to negative values.

Main motivation of central banks for adopting the policy differed from country to country. The ECB and the Sveriges Riksbank (Central Bank of Sweden) employed the NIRP to fight the expected low inflation and both institutions completed the policy through other unconventional monetary policy measures. On the other hand, the goal of the remaining two countries was to prevent massive capital inflows and to protect their currency (Jobst & Lin 2016; Bech & Malkhozov 2016).

So far, assessments of the experience with NIRP were fairly narrative, lacking substantial quantitative analysis of data. It is understandable if the very recent nature of the policy and resulting data unavailability is taken into account. This is also the reason why this thesis attempts to conduct a Vector Autoregression (VAR) model, to provide more evidence from the experience of the participating countries. From few studies that were published until now, Jensen & Spange (2015) and Bech & Malkhozov (2016) argue that the pass-through of negative interest rates into market interest rates was not weakened

by setting rates negative. However, transmission into retail rates (lending and deposit rates) was not even partially complete. Jobst & Lin (2016) consider the impact on the banking sector and conclude that the NIRP tends to establish a trade-off between transmission of the interest rate shock to the economy and bank profitability, due to sticky deposits. Furthermore, those effects should be carefully watched in considerations of further deepening the rates. On the other hand, when considered on the country specific basis instead of the aggregate level, Turk (2016) argues bank profits were untouched (conclusion based on cases of Denmark and Sweden).

The International Monetary Fund (IMF) released a policy paper in March 2017 evaluating the performance of the NIRPs (IMF 2017). The main findings include a positive impact on the situation of the monetary policies arguing no substantial side effects have been produced (bank profitability preserved, payment systems working well etc.). Nevertheless, the IMF staff argue that effective lower bound remains the problem encouraging further focus on monetary policy tools capable of deepening the rates further.

In conclusion, the research literature is rich on the NIRP in general, as well as on the ZLB and its implications. The topic undergoes huge discussions recently, and as it is noted in the introduction, it is urgent to meticulously scrutinize the tools to overcome lower bound of interest rates, to be prepared for potential turbulent times of the economy. Therefore, the topic is very relevant nowadays and the search into the literature resources showed a practical view on the introduction of the policy is missing. Thus, it would be beneficial to complete the academic discussion with a practical country specific application.

Chapter 3

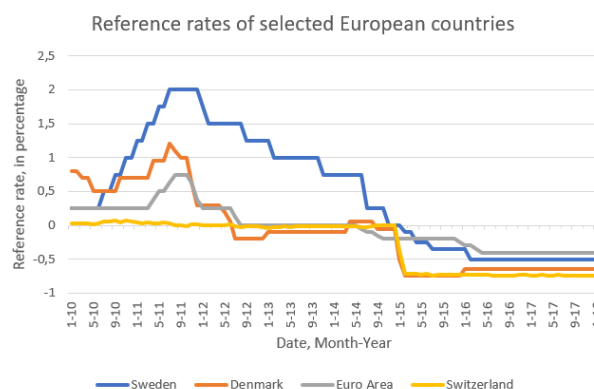
Empirical evidence from European Countries

3.1 VAR model analysis of the interest rate pass-through

3.1.1 Motivation

As mentioned previously, the unconventional monetary measure of setting main policy rates in the negative territory has already been introduced by a few countries in Europe. Denmark pioneered it in July 2012 by letting the Certificate of Deposit rate to drop to -0,2%. The ECB and the Central Bank of Sweden followed and made their deposit rate negative for the first time in June and July 2014 respectively. Together with Switzerland joining in January 2015, all 4 institutions keep their main policy rate negative still today.

Figure 3.1: Evolution of reference rates



Source: Respective central banks data reporting

Before proceeding to the investigation of the practical issues related to the introduction of negative interest rates at the cash desk of the Czech National Bank as the main exercise of this thesis, an empirical analysis of the data from countries that have already opted for utilising this monetary policy tool will be provided. To the best of my knowledge, no substantial empirical analysis has been done investigating the most recent data from countries adopting NIRP. Furthermore, the interest rate pass-through in countries under NIRP has not been studied through the VAR model analysis.

Several studies were published investigating the interest-rate pass-through at (or very close to) the zero lower bound (Nakajima 2011; Binning & Bjørnland 2017; Chattopadhyay & Ghosh 2016; Grisse & Schumacher 2017). The most recent paper linked to the NIRP performed the Markov Regime Switching with Time Varying Transition Probabilities model on data concerning Denmark for the period when negative policy rates have been in place (Khayat 2018). The effect of requiring negative interest rate payments on reserves were investigated and the author concluded that the policy caused a decrease in value of the currency as well as significant outflows from banks (Khayat 2018). Additionally, Horvath *et al.* (2018) provided an analysis of data from the Euro Area, using heterogeneous panel cointegration methods to reveal the nature of the pass-through under QE and NIRP policies. Nevertheless, authors did not find enough evidence of weakened response of bank rates towards policy rate in the period of negative interest rates.

The VAR model approach is a widely used tool to investigate, describe and forecast interest rate pass-through mechanism (Mojon & Peersman 2001; Burgstaller 2005; Havránek *et al.* 2012; Saborowski & Weber 2013; Hálová 2015; Kolcunová 2017). The VAR model analysis is therefore a relevant approach to study the interest rate transmission. Together with the lack of empirical research, describing the nature of the interest rate pass-through under specific NIRP conditions, a research question can be asked whether the main economic variables react similarly to shocks in interest rate as they do under positive policy rates.

I am aware of the temporal shortcomings in the used data, which is still present today. However, to contribute to the discussion on the effectiveness of the NIRP, I first attempted to study the available data. A simple VAR is employed in this case because of the restricted data availability. The usage of advanced and sophisticated variants of the model would be inappropriate for the present case of limited sample size. Those models would require substan-

tially longer time series to perform well. Consequently, it would be suggested for future research interested in the field to perform other restrictive types of VAR models or structural Panel VAR models inspired by Saborowski & Weber (2013) or Kolcunová (2017) depending on the nature and extent of datasets. Furthermore, Bayesian VAR model could be used for more in-depth analysis as well, however, some empirical evidence is needed first to set the prior of the model correctly. Today, it would be very difficult to argue to what extent the transmission follows the pattern found with positive interest rates and therefore the results would be biased.

Thus, the following chapter will examine the transmission of the one standard deviation shock in interest rate to the main economic variables of the previously mentioned countries separately, employing a simple VAR analysis. The limitations based on the sample size will be considered while interpreting the results.

3.1.2 Dataset Description

For the analyses, monthly data of the main macroeconomic variables were chosen: real gross domestic product (GDP), market interest rates (IR) and inflation (Harmonised Index of Consumer Prices - HICP).

Observations up to the end of the year 2017 are studied exploiting all the information available at the moment. For Sweden and the Euro Area, 6 months preceding the introduction of the reference rate into negative values are included to let the shock fully realize, and to increase the sample size slightly to achieve the most viable results possible under given conditions. 48 observations are investigated for Sweden (M012014 - M122017) and 49 observations constitute the sample of the Euro Area (M122013 - M122017). In case of Switzerland, the very beginning of the policy is employed as t_0 in order to avoid the impact of the cease in exchange rate interventions regime, which caused important fluctuations of exchange rate during the second half of 2014. Thus 36 observations are studied in case of Switzerland (M012015 - M122017). As first Denmark's decrease under zero bound was only minor, the first month of the policy is set as time t_0 . Therefore, 66 observations are studied (M072012 - M122017).

All series originate from Eurostat database except for market interest rates of Switzerland (3-month CH Libor) that come from the database of Swiss National Bank. Data for IR and HICP variables are used in monthly frequency. Real GDP is the only series having quarterly data format as the highest data

frequency available. Therefore, cubic spline interpolation is used to extend quarterly data to their monthly estimates and those are used in the dataset.¹ Harmonised Index of Consumer Prices is employed as the measure of inflation for all countries. The following Table 3.1 summarizes information about the dataset.

Table 3.1: Variables

	Source	Name of series	Series ID
GDP	Eurostat	chain linked volumes (2010), millions of euros, seasonally adjusted	namq_10_gdp
HICP	Swiss National Bank	London, Libor - CHF - 3-month	zimoma
HICP	Eurostat	HICP (2015 = 100) - monthly data (index)	prc_hicp_midx
IR	Eurostat	Money market interest rates - monthly data	irt_st_m4

3.2 Methodology - VAR model

According to Pffaf (2008), VAR(p) model in general can be presented as follows:

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + C D_t + u_t$$

where $y_t = (y_{1t}, \dots, y_{kt})^T$ is the vector of endogenous variables, $u_t = u_1, \dots, u_k$ is the vector of white noise terms and A_i for $i = 1, \dots, p$ is the $K \times K$ matrix of parameters. D_t is the $(M \times 1)$ column vector of deterministic terms and C is the matrix of parameters for deterministic regressors of dimensions $(K \times M)$. Deterministic regressors can contain terms such as trend, intercept or/and seasonal dummy variables. It is assumed that u_t has constant mean and $E(u_t u_t^T)$ is a time-invariant positive definite covariance matrix.

Orthogonalized impulse response functions of shocks identified by Cholesky decomposition will be investigated as output of the analysis. As VAR model setup represents a dynamic system of interacting variables interpretation of individual estimates is not possible.

¹Data for last two months beyond the interpolation are extrapolated based on the growth rate of respective industrial production data available in monthly frequency

Stationarity

Stationarity of the respective series as the crucial assumption for VAR model needs to be studied in more detail. Time series are considered stationary if their mean, variance and autocovariances are constant for each given lag (Brooks 2008). Two testing procedures for discovering the unit root process are employed: Augmented Dicky-Fuller (ADF) test as a commonly used test and Phillips-Perron Unit Root (PP) test that is advantageous as it deals with potential heteroskedasticity and serial correlation in errors. Moreover the method of PP test does not require the lag length to be specified.

Firstly, GDP and HICP series are treated in logarithms which is a way to partially offset non-stationary nature of data. On the other hand, negative values of interest rates suggest IR variable should be considered in level form. Graphical observation as well as testing procedures are used to check stationarity of all four datasets' variables. Graphical representations show data (log_GDP, log_HICP, IR) are not stationary, moreover they are trending over time (the visualization can be found in the Appendix: Figure A.1, Figure A.2). This implies that the mean value is not constant consequently suggesting violation of the main assumption. This evidence is further supported by the results of the ADF test and the PP test, that do not provide enough evidence to reject the null hypothesis of unit root process even at 5% level for all except two cases, tested by the PP test and one value tested by ADF test. This specification of input variables did not provide satisfying results of impulse responses neither null hypotheses of unit root tests were rejected.

Thus, first-differencing as a traditional method is used to correct for non-stationarities (Wooldridge 2012). Tests suggest that the null hypotheses of unit root process can be rejected in majority of cases. The results of the PP test seem to provide more consistent results. The inconsistency of results provided by the ADF and the PP tests can be explained by the dependence of the ADF test on the choice of optimal lag length which can be high in case of small samples. Consequently, the results provided by PP test will be followed as it calculates heteroskedasticity and correlation robust statistic without a necessity to choose lag length externally. Results of the ADF and PP tests of both non-differenced and differenced data are provided in Table A.1.

Even though stationary natures of the GDP data for Switzerland and the Euro Area are not achieved even after differencing, the analysis is delivered as it is suggested that the VAR model can be studied with non-stationary data series

as long as it is stable as a whole (Lutkepohl 2006). Consequently, stability of the VAR system is studied in more details later on, to further prove the validity of the results provided by the studied models.

3.2.1 Model specifications and lag length selections

This exercise uses the most simple form of the VAR model employing only three variables: real gross domestic product (GDP), inflation (HICP) and interest rate (IR). The choice of only three main macroeconomic variables was based on the fact that only short time series are available. As the dataset is limited, a broader model, in terms of both variables and specifications, would not be suggested as those elaborated models perform well on large datasets. The most simple model should provide us with indicative results on the nature of transmission of an IR shock to the economy in NIRP environment. It could be later extended and variables such as financial market indicators, oil prices, exchange rate etc. could be added.

As suggested by Mojon & Peersman (2001), Havránek *et al.* (2012), and Kolcunová (2017), the usual way to order the variables is as follows: log_GDP, log_HICP and IR. Moreover, for this specific case of 3 variables only, the placement of IR to the last place is important. The reasoning lies in the fact that it can influence the remaining two variables merely with a lag. The differenced form of the data that was previously tested for stationary nature is used.

A decisive part of building a correct VAR model is the lag length selection. Widely used approach is to follow the suggestions of information criteria. The following information criteria are respected in the choice of lag length: Schwartz Information Criterion (SIC), Akaike Information Criterion (AIC), Hannan-Quinn criterium (HQ) and Final Prediction Error (FPE). Ivanov & Kilian (2005) studied 6 different possibilities evaluating their performance and the accuracy of the resulting impulse response functions based on the mean-square error metric. The AIC was identified as the most precise for monthly frequency data series. Ivanov & Kilian (2005) also argue that in small samples comparable to the studied cases, the SIC largely underestimates the optimal lag order. Nevertheless, this negative bias is outweighed by a large decrease in variance.

For all VAR model estimations except for Denmark, I continue to use 3 lags. In the case of Denmark, 2 lag order is suggested by SIC/HQ using conventional 10 lags as maximum length investigated. For Switzerland, I opt for 3 lags

suggested by the AIC or the SIC setting maximum lag length to 25 lags. High suggested lag lengths in case of the remaining two countries result from the low number of observations. However, I also employ 3 lag specification to keep the models parsimonious, taking into account the specificities of the dataset. The small number of observations is critical in the decision process regarding the number of lags in the model as well so the limited data availability is the reason why I selected the lowest possible level of lag length.

Additional testing procedures

Furthermore, diagnostic tests are performed to prove lack of heteroskedasticity and serial correlation in errors following arguments of Pffaf (2008). One of the advantages of the Impulse Response Functions interpretation is that they are orthogonalised and backed by bootstrapped confidence intervals which control for standard mistakes. However, due to fragile nature of the models, more testing procedures are run to check the strength of the results.

The Arch test for multivariate case is performed to discover the potential heteroskedasticity. In addition, the Portmanteau test helps in revealing serial correlation in the models. Results of these tests are reported in Table 3.2 and it shows that none of the tests reject null hypothesis of either no heteroskedasticity or no serial correlation at conventional 5% level.

Moreover, the Portmanteau test is also used by Ivanov & Kilian (2005) as a way of determining the correct lag length. The null hypothesis is not rejected in any case implying the lag selection is not incorrect.

Table 3.2: Homoskedasticity and no serial correlation tests of VAR models

p-values	ARCH test	Portmanteau test
Denmark	0.0551	0.5014
Switzerland	0.8281	0.9966
Sweden	0.7419	0.7626
Euro Area	0.2867	0.6296

Source: Author's calculations

3.2.2 Stability of the VAR model

The structural stability of the models as whole needs to be satisfied to consider any inference of the models valid. Two different checks of this property were

carried out.

Firstly, the OLS-CUSUM test (cumulative sum of recursive residuals test) was performed to check the stability of the models. The model is considered stable if the variable responses do not cross the red lines corresponding to chosen level of significance. Graphical representations are provided in the Appendix A, Figure A.3, Figure A.4, Figure A.5, Figure A.6 and the stability of the models for all four countries can be concluded based on this test.

Secondly, Lutkepohl (2006) presents that the stability condition of any VAR(p) model is equivalent to the fact that all eigenvalues of the companion matrix lie inside the unit circle. This condition is checked for the VAR models of each country that I investigate in the analysis, and all of them are stable according to this condition (graphs are available in the Appendix A: Figure A.7, Figure A.8, Figure A.9, Figure A.10)

In conclusion, the estimated models are stable with homoskedastic and serially uncorrelated errors which allow for providing orthogonal impulse response functions corresponding to each country's VAR model and to interpret responses to a conventional one standard deviation positive exogenous shock to interest rates. Responses to a negative shock are symmetric by the nature of the VAR model.

3.3 Results

Red dashed lines delimit 90% bootstrap confidence intervals of the responses. Significant response is observed when the displayed confidence interval does not contain zero value. The comments on the magnitude of the shocks are not straightforward in this example as first-differenced series are investigated. Therefore, the interpretations will be focused on significance and general patterns.

Assuming the world is in a state of positive interest rates, most macroeconomic textbooks would expect gross domestic product to rise with decreasing interest rates as saving becomes less attractive. Similarly, inflation would be expected to rise after a drop in interest rates as money becomes cheaper and agents are encouraged to spend more. The results under negative interest rate environment are going to be presented in the next part.

Denmark

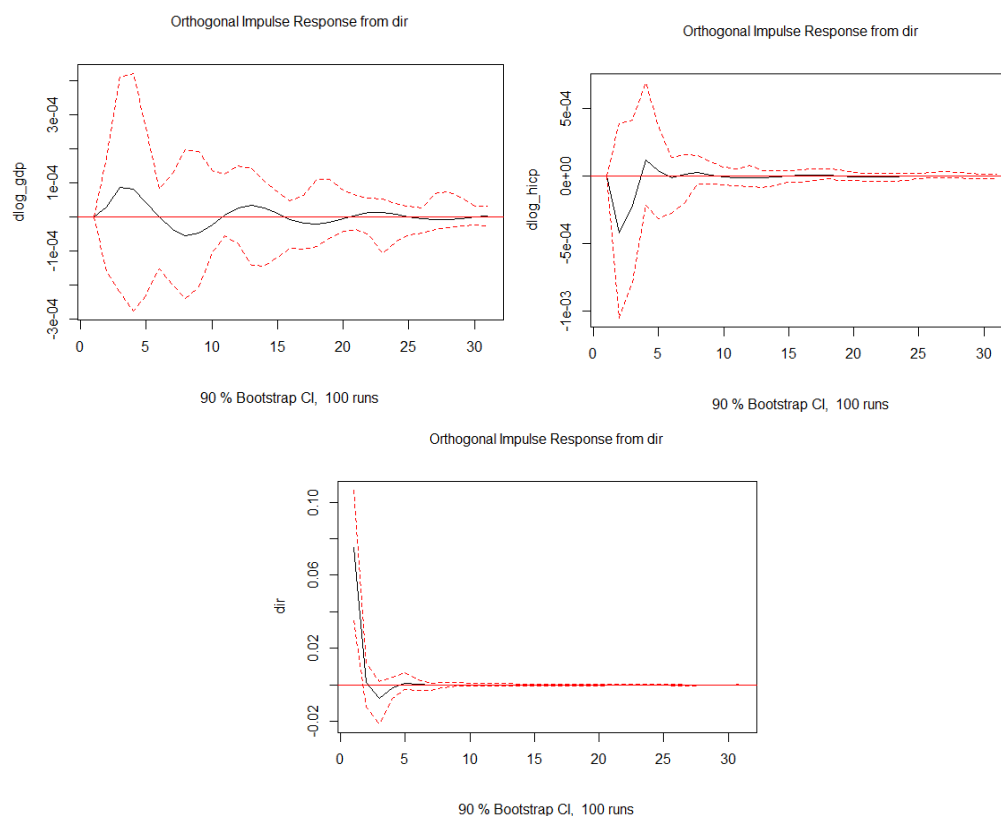
Denmark introduced negative interest rates in July 2012 (Turk 2016). This fact allows the analysis to consider 66 observations for each variable, which is the longest series of the empirical analysis.

The responses of the real GDP and inflation are dynamic, though not significant. The effect on the GDP variable is at first a slight increase followed by a decrease below the zero level and the fluctuations last until approximately 20th period. However, the response seems to stabilize after 30 periods.

Response of the inflation variable is firstly negative, rises to slightly positive value and stays at zero level after the 5th period. Fluctuations in responses, mainly of the GDP variable, indicate the transmission under negative interest rates do not follow the usual patterns that apply in case of shocks to positive rates.

A shock to IR is transmitted to a dramatical decrease in the variable itself, which is significant till the second period after the shock. Afterwards, the response is not significant, becomes negative, and stabilises at zero in the 5th period and the response vanishes completely after the 8th period.

Figure 3.2: Denmark - differenced series, 2 lags



Source: Author's calculations

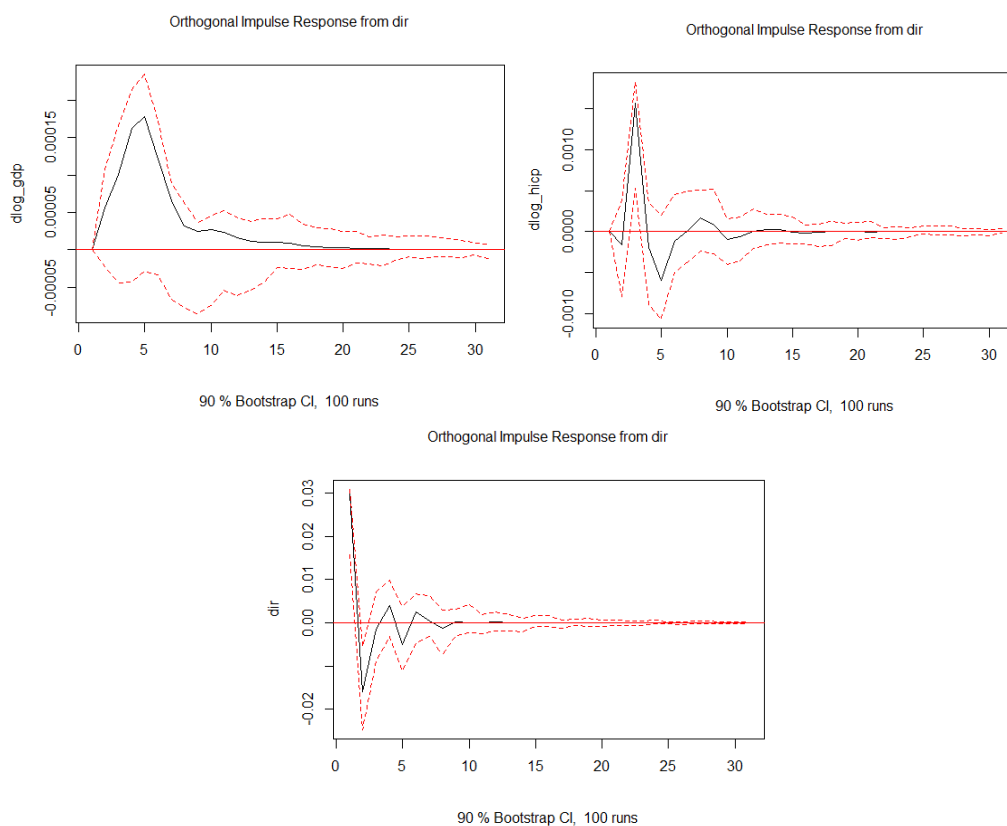
Switzerland

In case of Switzerland, the GDP variable reacts by significant rise peaking in the fifth period. Afterwards the reaction falls to zero level approximately in period 15. However, the whole response is insignificant and confidence interval takes even more time to collapse to zero.

For the case of inflation, the reaction to a one standard deviation shock is very volatile. Slight immediate decrease is followed by sharp increase in the 2nd period reaching its maximum in the 3rd period. This increase is statistically significant. Decreasing to negative territory in the 5th period, reaction is stabilised at zero level after the period 10. From period 5 onwards, the result is insignificant.

Shock resistance period is shorter for IR variable. Similarly to the previous example of Denmark, own response of interest rate is a huge significant drop in the first two periods. However, in this case also the drop into negative territory is significant and more severe. Shock stabilizes and vanishes after approximately 10 periods after minor fluctuations.

Figure 3.3: Switzerland - differenced series, 3 lags



Source: Author's calculations

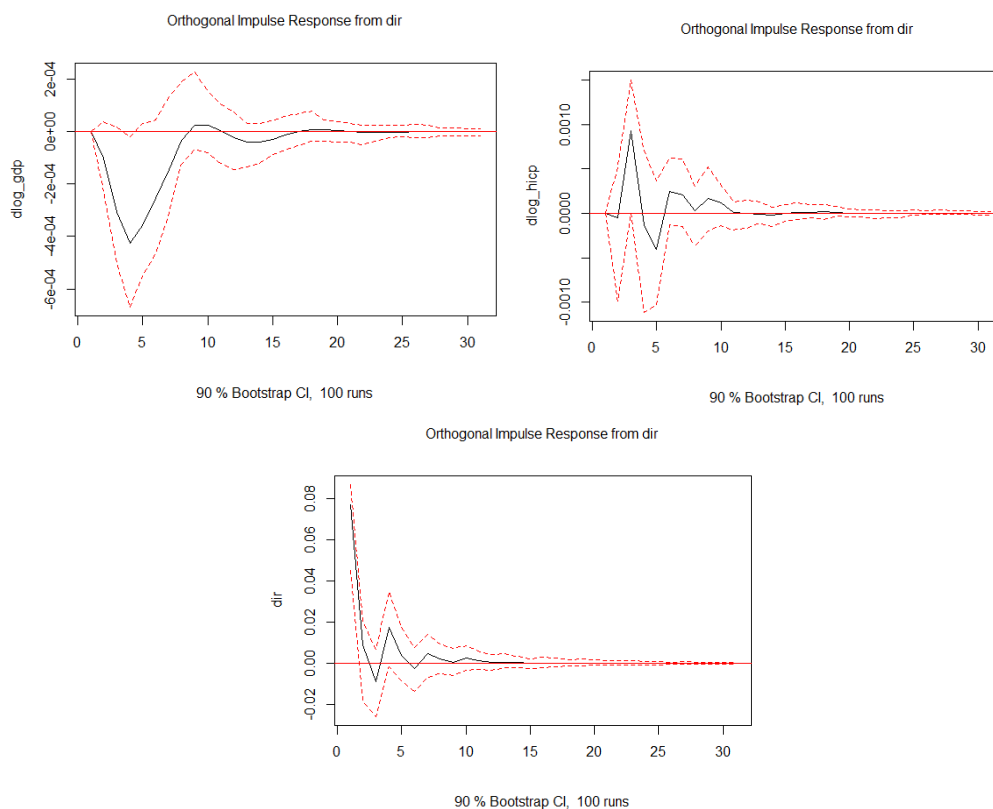
Sweden

Sweden introduced reference rate below zero in July 2014. To fully see the shock transmitted, 6 periods before the latter mentioned date were added to analysis.

Response of the real GDP is a sharp fall until period 5. It gradually increases to zero level where it remains after 10th period, showing only minimal fluctuations. The response is significant only at the very moment of reaching the minimum. Otherwise, the response is not statistically different from zero. Secondly, response of inflation is not significant. HICP reacts to the one standard deviation shock by increasing the price level after a minor drop during first period. This is, however, not a permanent state and the response fluctuates till stabilising at zero after the 15th period.

Interest rate responds to one standard deviation shock by decreasing substantially during the first few periods, drop in the positive territory being significant. After slight decrease into negative territory, which is not significant, the response fluctuates and decreases till reaching zero level. It vanishes after 10 periods.

Figure 3.4: Sweden - differenced data, 3 lags



Source: Author's calculations

Euro Area

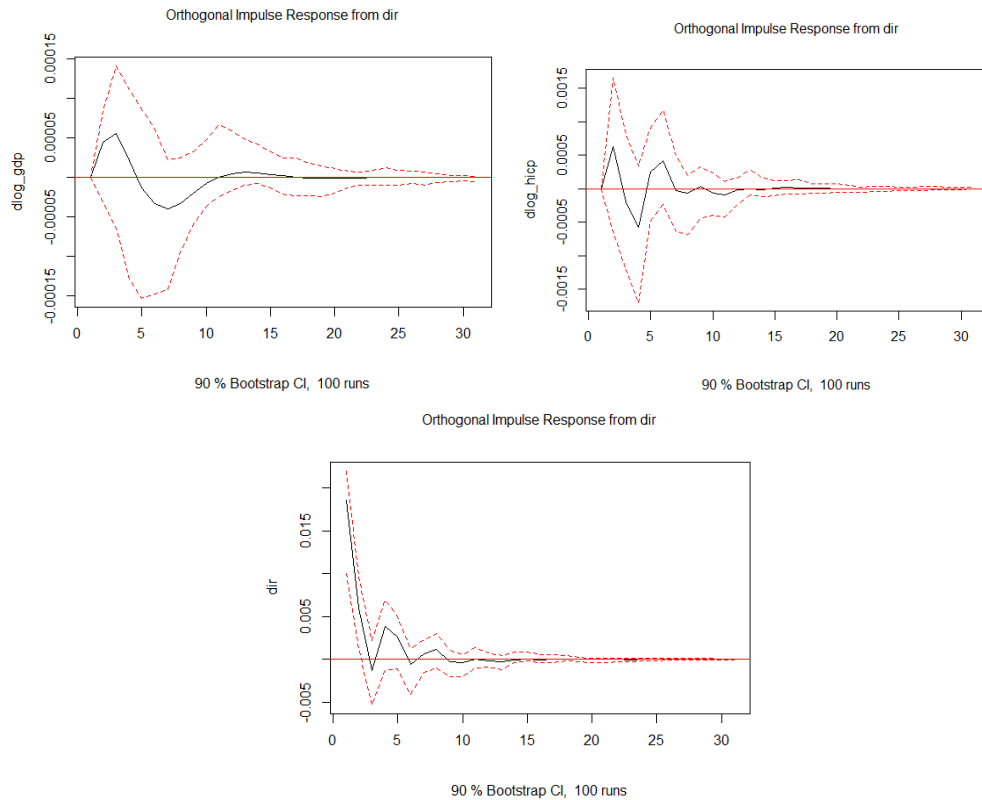
European Central Bank decided to push the deposit rate below zero in the announcement of 11th June 2014. As previously discussed, the data for 6 previous months are used for the sake of full shock realisation. Thus the time series comprise data from M122013 till M122017 (49 observations).

The response of the real GDP to a one standard deviation shock to market interest rate is not statistically different from zero. It is slightly positive for 3 periods, continues into negative numbers till the 10th period after which the response stabilizes at zero.

Similarly to the response of the GDP, the response of the HICP is not significant as the confidence interval contains zero in both cases. The inflation variable reacts dynamically to the shock. Response fluctuates during the first 10 periods and then stabilizes at zero level.

Pattern of IR response to the shock is similar to previous cases, with sharp significant decline during first 3-4 periods. Afterwards, the reaction is no longer significant. After being slightly negative, the response take approximately 10 more periods to disappear completely.

Figure 3.5: Euro Area - differenced data, 3 lags



Source: Author's calculations

Conclusion

Even though this exercise failed to provide solid statistical evidence on the nature of the responses to an exogenous one standard deviation shock to interest rate on 3 main macroeconomic variables, it can be implied that the transmission of the shock might not follow the traditional intuitive pattern and thus might not be completely functional under negative interest rates. There are two possible explanations.

Firstly, the inference from the exercise is limited by the number of observations available. This exercise was, as suggested before, the first attempt to study data of pioneering countries in the domain of negative interest rate policy implementation. Taking into account that the introduction of the measure by the first country (Denmark) allowed only for 66 observations, it is clear that even though the models are stable and satisfy the assumptions, results inferred from the models can have strong limitations. I suggest to repeat the exercise later on with substantially more observations available which would also allow for a more elaborated VAR model specification.

Secondly, assuming the model is correct, results indicate some non - functionalities in the studied transmission. This can be due to the effective lower bound of interest rates which can clearly be below zero. This effective lower bound is likely to prevent the transmission of the shock to be fully effective as economic agents rely on the fact that, technically, the market interest rates cannot go deeper into negative territory. These technical obstacles include law regulations, banks voluntarily shielding clients from higher costs on deposits accounts and the possibility of cash transactions usage instead of electronic money. All these problems could be the reasons behind an ineffective transmission mechanism which could be implied by the results of my analysis.

Consequently, as doubts about the effectiveness of the monetary policy under zero or effective lower bound have been raised even before, some researchers became interested in the issues of zero lower bound and in potential solutions on how to eliminate this obstacle. Possibility of deepening the reference rates further could be a solution to correct the transmission mechanism. It is also essential for the case of the Czech Republic to establish a plan to escape from the ZLB problem in case negative interest rates are needed to support monetary policy of the Czech National Bank in a future crisis. The text will continue by discussing recently proposed solutions and then by applying the most relevant and feasible steps to the Czech Republic environment.

Chapter 4

How could the Zero Lower Bound be overcome?

First of all, let me make a note on the terminology as there can arise a misleading sense of the ZLB. ZLB is a widely used term throughout the literature describing the major threshold under which cash holdings are more advantageous than electronic currency, which is bearing negative interest. The term of Effective Lower Bound (ELB) relates to the effective level of interest, at which economic agents would actually turn to cash, taking into account all costs of holding, insuring and transporting the physical cash notes and coins which could be negative with regard to recent empirical findings of Kolcunová (2017). The strategy should, however, face the problem of cash holdings as a way to escape from the NIRP in general so in this thesis I will follow the general flow of the literature and reference the problem as the Zero Lower Bound even though it can lie below zero.

4.1 What are the possibilities?

Gesell (1916) pioneered the problem by introducing revolutionary solution of "stamped currency". Decreasing value of paper money by this form of taxation should have prevented people from holding pieces of currency at home, thus making negative bank interest rates effective. Both Goodfriend (2000) and Buiter & Panigirtzoglou (2003) also based their solutions on levying tax on paper notes thus decreasing their value below par.

This idea of "currency carry tax" is later reviewed also by Fukao (2005) and Buiter (2005) who suggest to employ stamp money as a tool in helping Japanese

economy out of deflationary vicious circle by means of negative nominal interest rates. Fukao (2005) is a proponent of taxing all government-backed financial assets so they provide negative real returns. Buiter (2005) considers the latter solution complicated and completes the discussion with a suggestion based on Eisler's proposal of two simultaneous currencies. Eisler (1932) was in fact the first economist who indicated that electronic and paper money should be treated separately and that this distinction has its positive attributes.

Much more recent work building upon the idea of electronic money becoming the main unit of account was proposed by several researchers (Buiter 2009; Agarwal & Kimball 2015; Rogoff 2017). A practical and detailed solution leading to the elimination of the binding lower level on interest rates will be provided in the next part. The main point based on ideas suggested also by Buiter & Panigirtzoglou (2003) and Buiter (2009), lies in the fact that commercial banks with their assets as a part of base money, could easily pay interests to central banks and this measure would come at almost no cost. Agarwal & Kimball (2015) stated that the best way to decrease the value of paper currency is to attack net deposits at the cash desk of central banks.

The main problem that arises naturally, while thinking about negative market interest rates is the possibility of using paper currency. As soon as negative interest rate is levied on regular deposit accounts, economic agents have incentives to withdraw money and continue to store or to use paper currency in daily transactions. Therefore, the transmission of negative interest rates into economy is likely not to be realised fully and effectively.

Solutions to the ZLB problem could be summarized into 5 main possible paths: 1) Helicopter Money; 2) Increased inflation target backed by strong forward guidance; 3) Tax Paper Currency; 4) Complete or partial abolition of cash; 5) Time-varying exchange rate between electronic and paper currency. This text will focus on the last proposition but other possibilities frequently mentioned in economic papers will shortly be described first.

Helicopter money is a controversial approach to monetary policy that consists of providing public with money for free. In other words, central bank inserts sums of money into the economy in search of stimulating demand. The policy is mentioned for example by Reifschneider & Williams (1999) or discussed in more depth by Buiter (2014). It is a theoretical, extreme form of monetary policy still today. However, there are growing debates on its viability and possibly the necessity of the solution. Recently, a novel approach to helicopter money was suggested by Hampl & Havranek (2018) who propose

to employ digital currency to directly stimulate consumption. The authors present a plan, in which all economic agents would have access to a digital wallet that would be supplied with resources available only temporarily or subject to significantly negative interest rates to promote immediate spending.

Inflation targeting, in contrast, is widely used conventional monetary policy which strongly depends on the credibility of steps taken by central banks. It has been suggested that higher targeted inflation would prevent interest rates from hitting their lower bound (Blanchard *et al.* 2010). Some researchers opposed this idea and argued that it will not help the economy to escape from problems of effective lower bound (Buiter 2015a; Goodfriend 2015) and that it could induce costs of price level variation (Fischer 2016). Taxing paper currency was one of the first ideas on the topic (Gesell 1916; Goodfriend 2000) but those propositions are impractical and unlikely to be considered by policy makers today.

The fourth proposition is related to paper currency itself which has been blamed for being the main cause of binding lower bound. It is agreed that there are no difficulties on paying negative interest on reserves stored electronically, but as soon as physical cash is available, people would naturally switch to using paper currency instead of bank deposits. Apparently, total elimination of cash would ensure the ZLB is not a problem any more. Buiter (2009) argues that eliminating cash would be an efficient way to tackle the problem as all other financial instruments are registered and could bear interest. Rogoff (2016) advocates that “less-cash” economy would not only allow central banks to benefit from negative interest rates but also contribute to the fight against criminal activities that are often financed with cash. In his book, Rogoff presents a solution towards eliminating large-denomination notes as a way to allow for minor regular transactions but prevent large and anonymous payments.

Even though elimination of cash can seem to be a drastic solution, fast technological progress guides us to completely digital era where majority of payments are done electronically. The fifth proposition embodies an element of electronic money as well and is backed by several researchers (Buiter 2009; Agarwal & Kimball 2015; Rogoff 2016; 2017). Electronic money should replace paper money in the role of the main payment tool and a time-varying exchange rate between paper money and electronic money should be established in order to force the value of paper money to depreciate together with electronic money that bears negative interest rate. More time will be dedicated to explain the latter solution as it is the main inspiration for the case study.

4.2 Steps to overcome the Zero Lower Bound

Setting up the procedure to let the paper currency lose value should allow policy makers to avoid adverse consequences of the ZLB. The first step of the plan is to define electronic money to become the main unit of account (Agarwal & Kimball 2015; Rogoff 2017). More strict version is stated by Buiter (2009) who suggests to separate numéraire and medium of exchange functions of money. Buiter (2009) builds upon Eisler's proposal which suggested to unbundle the medium of payment and unit of account role of money and establish a new virtual currency that would take on the function of means of payment. The physical old fiat money would be abolished and left only as numerical reference or unit of account in contracts (wage and price transactions) or tax payments. A new form of money that author calls "wim currency" would be created and serve for regular transactions. The lower bound would exist only related to the wim currency and not to the original one, where negative interest rates can be finally levied.

Electronic version of currency does not seem revolutionary any more with regard to huge technological progress that has been hitting financial sector for a decade now. An enormous value of 323.6 billion EUR was paid at terminals by card in the European Union in 2016 (Statistical Data warehouse of European Central Bank) and the number of electronic payments continues to follow an increasing trend for several years. Phenomena such as block chain, electronic currencies and mobile payments are making electronic money more accessible, convenient, and quicker compared to paper currency. However, adjustments to the legal system would be needed as well as review of technological readiness of all agents in the economy to be prepared for the change.

Secondly, so called "time-varying paper deposit fee" should be introduced (Agarwal & Kimball 2015). It would be imposed on transactions between private banks and the central bank. This special reference rate would be set by the central bank and would co-move with other reference rates such as deposit or repo rate, increasing when reference rate becomes more negative and decreasing when the rate returns to positive values. In other words, private banks would not benefit from guaranteed zero interest rate while depositing paper money at the cash desk of the central bank any more. Thus, both way functioning machine would be established. Net deposits at the cash desk of the central banks would cost a fee based on the actual Paper Currency Exchange Rate (PCIR) and, vice - versa, cash would be provided on discount when a

bank withdraws money from its account. The exchange rate would be equal to $(1 - \text{deposit fee})$ and it is assumed that banks would not be willing to bear the deposit fee themselves (Agarwal & Kimball 2015). Consequently, paper currency is expected to be offered on discount at private banks as well to recover for the fee. This point of the plan requires that capabilities of central bank are reviewed and procedures of levying interest rates are checked to attribute the role of exchange rate setting to national central bank.

Related to the second step, pass-through into retail transactions could be questioned. Comparison to credit and debit cards transactions is provided by Agarwal & Kimball (2015) who argue that fees are already levied on electronic payments, which in small shops make owners unwilling to offer customers this payment possibility. In other words, cash transactions would need to include a fee for using this payment method in the period of negative interest rates which would make both means of payment equally costly as the successive redeposit of cash in a bank would be liable to the exchange rate. This focus on redepositing money in a bank was identified as the most effective way how to remove the zero lower bound. Agarwal & Kimball (2015), therefore, concludes that equal treatment of payment methods would be ensured by this policy as neither transaction would be provided at par any more.

It is important to consider both the advantages and disadvantages of the solution as well. Firstly, it is advocated that no additional complicated regulation is needed to put the proposed ideas in place (Agarwal & Kimball 2015). A quick implementation in the time of need is another vital attribute that is worth mentioning. Together, the solution would be ready to use when the next crisis hits the world economy and countries would have easy solution to revive their economies. The possibility to focus on lower levels of inflation bringing price stability increases the added value of the solution (Buiter 2009) and it is also claimed to be the “true price stability” by Bordo & Levin (2017). Targeting zero inflation would be a way to possibly eliminate inflation completely (Agarwal & Kimball 2015) which is an idea discussed also by Ben Bernanke, the former chairman of the Federal Reserve (Bernanke 2013).

However, there are problems and technical issues that must be treated with caution so that an easy transition to the new system is possible. These issues are related mostly to legal regulations as they consider paper currency automatically at par value. This could be problematic in debt contracts and penalties where agents would be rewarded for borrowing money or for commit-

ing a crime. Those complications will be discussed in the case study centred on the Czech case. Moreover, Rogoff (2017) raises issues about the solution mentioning its necessary condition which assumes that all actors on the market cooperate and accept electronic money as the unit of account, both public and private. Agarwal & Kimball (2015) add that costs of confusion between real and nominal value of money could be increased. Additionally, as soon as the recession is over and negative rates are not longer needed, nominal discrepancies could cause problems to other monetary policies (Rogoff 2017) so it is important to review possibilities of restoring the state of the currency to par value.

Four different possibilities concerning the procedure of returning paper money to par value are suggested by Agarwal & Kimball (2015) to draw a full picture for central banks on the whole process related to elimination of the zero bound. “Swift return to par” consisting of quick return to original zero value is discouraged for usage as it would create space for speculators benefiting from the spread between paper currency and other target interest rates. More intuitive approaches are “Gradual Return to Par” and “Friedman Rule”. Both of these solutions would suggest to follow the evolution of other target rate and either leave PCIR slightly around or equal to target rate respectively. The former way would ensure the ZLB does not cause problems at any moment even during the process of par value recovering. The latter solution would avoid deflationary period in unit of account which can be an interesting point for policy makers. Last proposition, “Seigniorage without Inflation”, includes decreasing value of cash further, to gain the power of seigniorage but still target no inflation. This way of letting paper currency stay below par at all times is equivalent to taxing paper currency notes. Those are the possibilities provided by Agarwal & Kimball (2015) and it is up to individual central banks to decide the most suitable path for their monetary policy.

The explained solution will now be applied to the environment of the Czech Republic and the problems that may arise in the Czech context will be discussed.

Chapter 5

How can CNB eliminate the Zero Lower Bound?

An alternative to drastic solutions such as a complete or partial removal of cash is introducing time-varying exchange rate between paper and electronic currency for central and private banks. This would increase political acceptability by mitigating psychological disagreement of the population as a concern. In the following chapter, a case study based research of the current state of the related areas, which would be affected by elimination of the zero lower bound of interest rates, will be delivered.

5.1 Methodology - Case Study

Empirical methodology used in this section is the closest to the Case Study Research (CSR) methodology and it will be used to deliver the task of overviewing the current state of the Czech environment in the context of negative interest rate introduction. (Woodside 2010, p. 1) defined the methodology as follows:

CSR is an inquiry that focuses on describing, understanding, predicting and/or controlling the individual (i.e., process, animal, person, household, organisation, group, industry, culture, or nationality).

As implied by the definition, the strategy is aimed at mapping and defining the studied phenomenon to the best and furthest possible extent but unlike in exact quantitative research methods, accuracy cannot be measured by statistical tests. Even though this methodology is still not widely accepted questioning the robustness of the results, it is substantially used in social science fields such

as sociology, psychology, and behavioural economics. There is growing literature supporting advantages of the case study research practice providing advice on the best practices that are suggested to be followed (Woodside 2010; Remenyi 2013; Yin 2014; Woodside *et al.* 2014; Gerring 2017). Relevant to my specific research topic, the case study methods were used in policies analyses (Geva-May 2005), accessing the development of a security policy (Alqahtani 2017) as well as in business oriented work on B2B Marketing and Purchasing (Woodside *et al.* 2014).

The study consists of investigating the legal grounds (legal acts and regulation on both Czech and European level) and systematic issues that could arise related to the NIRP introduction in the Czech Republic. In answering such qualitative questions, as are of the interest in this chapter, it would be impossible to employ more strict methodology, keeping in mind that the areas of investigation are wide ranging from law acts formulations to technical equipment needed for electronic purchases using publicly available statistical data.

First of all, the feasibility of introduction of negative interest rates according to current Czech legislation will be evaluated and the text will continue with questioning the ability of current situation to incorporate the strategy proposed by Agarwal & Kimball (2015) completed with ideas by Buiter (2009) and Rogoff (2017).

5.2 Negative values of IR: a problem in current legislation?

First of all, it is necessary to clarify the understanding of the word *interest* in the legal context of the Czech Republic. General perception of interest explains it as value received on money that is lent and a value paid on resources that are borrowed. Introduction of negative interest rates would force the change of this perception and thinking of the word interest would include a possibility of paying interest while lending money, and vice versa. Depositing money in a bank is equivalent to lending money as we provide source of financing for that financial institution. Under current conditions, a bank provides interest on deposited money and we understand it as reward for giving the bank the right to keep it. After interest rates become negative, this reward would become negative, meaning the depositor would pay for the service that bank provides.

On the other hand, presently, an interest on borrowed means is the fact of paying for the service of having money available now and repaying the sum later. Negative rates would translate it into offering money to economic agents with a bonus payment. Put differently, people would be paid for borrowing the money. It is clear that the current understanding of the word interest would be reversed in the state of the world with negative interest rates.

According to the New Civil Code that came into force in 2014 (Česko 2012), the word interest or interest rate is not strictly defined to be positive or negative. Negative interest on deposits could be implicitly found in the §513 of the Civil Code (Česko 2012, p. 111) which states that:

Interests, penalties for delay and costs related to collection of receivables are part of interest-bearing receivable.”¹

This means that negative interest rates could be interpreted as a part of interest-bearing financial claim (receivable), which is counter-intuitive as negative interest rate is more understood as an amount payable than a negative amount receivable.

Consequently, there is not a specific problem that would pose a serious obstacle to negative reference rate as such according to the Civil Code. Nevertheless, it is crucial to mention that the law does not consider interest rate being both positive and negative explicitly so it is likely that some interpretations of the individual acts can be misleading.

5.2.1 List of legal acts with reference to the policy IR

Confusion arises mostly while interpreting regulations that use reference rates or their multiples to calculate penalties, scholarships or other form of fees or rewards. Clearly, as soon as the reference rate is set negative, penalty would become a reward and vice versa. According to the explicit formulation, debtors would be required to pay a negative amount as a penalty for being delayed with repaying corresponding debt. In reality, it means that they would get paid for not obeying to the binding schedule of payments. Therefore, all individual acts relying on reference rates set by the CNB should be revised and reformulated to account for the case of reference rates set negative.

Being a student of economics, I cannot hope for providing an absolutely exhaustive enumeration of legal acts containing reference to the rates set by

¹Author's translation

the CNB. However, to the best of my knowledge, an extensive list of acts that would result in unintended conclusions is provided which is an important contribution of the thesis.

Repo rate

There are several regulations built upon the level of repo rate set by the CNB.

Firstly, **Decree No. 351/2013, §2**, on determining beyond other the level of penalties on delay (Gov 2017) specifies that the penalty on delay is calculated as repo rate + 8 percentage points. The level of repo rate on the first day of calendar half year in which the delay occurred is used. It is, however, almost sure that the final rate will be above zero level.

Moreover, **Act No. 190/2004 Coll., §15, part 3** on bonds sets the fee/interest for not emitting the bond in the predefined period based on repo rate. Weighted average of repo rates during the period from the day of payment for the bond and the day of the refund due to not emitting the actual bond is taken into consideration while calculating the interest that needs to be paid on the top of the refund.

There are several more acts mentioning repo rate in their calculations, however, the resulting amount is always further increased by percentage high enough that negative values are highly improbable.

Discount rate

Deposit rate is the most frequent reference rate that is being used as a base in calculations of resulting penalties or rewards. Acts concerning regular citizens and governmental organizations will be treated separately.

Firstly, the list of legislation having effect on citizens is provided.

Act No. 191/1950 Coll., §48, part 2 on bills and cheques establishes the calculation of due interests as penalty in case rules applying to bill transaction are not observed. The level of discount rate on the date of penalty execution is used.

Act No. 592/1992 Coll., §17, part 5 on general health insurance that adjusts the level of insurance premium, including penalties for cases of delays in payments. This act also mentions discount rate, which is given a crucial role in calculations of penalties. If the premium is paid by postal order, the person liable to process the transaction has 2 working days to transfer the money to the account of the insurance company. If the process fails to be finished within

2 working days, the institution holding postal licence is required to pay interest equal to twice the discount rate of the Czech National Bank (official rate that was valid on the first day of the quarter when the transaction was due).

Act No. 589/1992 Coll., §17, part 2 on social security insurance and contributions to governmental policy of employment uses the discount rate in calculation of interest on delays in overpayment refunds. Social security administration must refund the amount overpaid within 30 days from the finding of the discrepancy. If it fails to make the transaction, the administration is responsible for paying interest on the period of delay equal to the 140% of official discount rate of Czech National Bank holding on the first day of the relevant quarter.

Act No. 257/2016 Coll. on consumer loans takes into account the possibility of calculating the interest rate on loans based on reference rates of the Czech National Bank or other publicly known rates that could not be directly influenced. In this specific case, there is not only one paragraph that needs to be reformulated but rather the whole act would need to be reconsidered and adjusted for the possibility of reference rates of CNB to be negative.

Decree No. 141/2013, §2, part 6, on accommodation of legislation concerning mutual transfers of pension rights in accordance with EU pension system also employs reference discount rate. The act is concerned with method of determining the financial amount of pension for people partially working in the Czech Republic and abroad. In this particular case, discount rate is used to define interest rate on financial sum of the pension that is contributed to the EU pension system from the part of the Czech system.

Secondly, the legislation concerning governmental institutions that would be affected by the change of reference rates into negative territory is listed below.

Act No. 424/1991 Coll., §18, part 3 on political parties creation treats also the situations when political parties receive gifts or donations. The Act No. 424/1991 Coll. describes the kinds of gifts and donations that are acceptable and as soon as the party receives cash or both tangible or intangible presents that are not in line with this legislation, the act defines the procedure that should be undergone. The gift or donation should be returned and if the return is not possible, that state itself is entitled to be the recipient. The returning amount should include an interest that is equal to the appreciation of the value. And the latter interest is calculated as the rate equivalent to the

discount rate of CNB valid on the day of returning the donation multiplied by the amount returned.

Regulation No. 271/2000 Coll., §2, part 7 and 8 on the state contribution to operations of marine navigation and on financial contribution to education in marine profession abroad uses deposit rate for two situations. Students willing to proceed in the marine profession can apply for a loan provided by the Czech Republic. If students break a rule established by this Act, they are liable for returning the whole sum of the loan together with the interest that is calculated as twice the official discount rate valid in the time of breach of the rules times the amount of the loan.

Lombard rate

Lombard rate is rarely used as reference rate in the legislation, however, this reference rate of CNB is employed in penalizing institutions cooperating with the CNB. Relating to the **Act No. 227/2013 Coll.** that changes the Act 6/1993 on the Czech National Bank, Official announcement from 16 October 2016 establishes that the Czech National Bank has the right to demand interest as a penalty on a bank or other financial institution that is liable to hold required minimum reserves at national central bank and fail to do so. This interest is set to be twice the average lombard rate valid during the holding period times the amount by which the required minimal reserves were lower than the stipulated sum.

Conclusion

In case the zero lower bound was broken in the Czech economy and negative interest rates were possible to establish, the latter mentioned legislation would need to be reviewed and adjusted by policy makers to ensure that interpretation is clear not only under the assumption of positive interest rates environment but also in situation when the negative reference rates are employed.

5.2.2 Additional obstacles

Apart from misunderstandings that the existence of negative interest rates can create, it is essential to avoid any potential misuse of the policy in place. Four additional ideas constituting a potential threat to the fluent strategy implementation will be discussed. Firstly, accounts held by the CNB specifically

dedicated to public institutions and the government are subject to special treatment among all accounts. That fact could endanger the compliance with the ECB regulation on prohibition of monetary financing. Secondly, legislation concerning free reserves of private banks on accounts held by the CNB could leave the room for avoidance of negative interest bearing. Thirdly, cash repayment of debt at moments of depreciated paper currency would result in profit making channel for debtors taking advantage of the discrepancy between actual and par value of paper money. Lastly, tax authorities could become a storage of resources free from negative interest rate environment as excessive tax prepayments are not interest-bearing and would be returned unaffected by the NIRP.

Having regard to the Act No. 218/2000 Coll. and all changes summarized in the Act No. 501/2012 Coll., interest rates levied on accounts of government institutions held by the CNB are determined based on the agreement between the Ministry of Finance and Czech National Bank (§33, part 4)). Acts No. 218/2000 Coll. and subsequently No. 501/2012 Coll. also clarify that the Ministry of Finance should inform about nominal value equivalent to the interest payment on its website. The announcement valid since 1 March 2014 sets this value to 0.00% p.a. Moreover, based on conditions set by the CNB, deposits of government institutions are guaranteed not to bear any interest (CNB 2018).

However, one important fact needs to be taken into consideration here. Interest rates from those accounts are income of the state budget and fees related to their operation are expenses of the state budget (Act No. 501/2012 Coll., §52, part 7). European Central Bank in its Decision of the European Central Bank of 20 February 2014 on the prohibition of monetary financing and the remuneration of government deposits by national central banks (ECB 2014b) sets the ceilings of interest rates for government deposits in central bank accounts to overnight deposit comparable to EONIA or to fixed term deposit rate comparable to EUREPO (if the accounts are not denominated in EUR). In other words, this interest rate levied on public institution and government accounts in CZK must always be lower than reference rates given by the CNB. Thus, keeping the interest rate on those accounts at zero level during the period of negative reference rates would create a possibility of monetary financing which is prohibited by the letter mentioned act. Therefore, the exact value or range of values for interest rates levied on accounts of governments and public institutions should be set with regard to this limitation.

From more general perspective, there is another additional problem that

could prevent a fluent transition to negative interest rates. Zero interest rate is levied on so called free reserves according to the Official Announcement of the Czech National Bank from 31 October 2016 concerning the Act No. 6/1993 Coll. on the Czech National Bank (CNB 2016). Free reserves are resources that private banks keep in the national central bank beyond the level of minimum reserves that are required. Those bank resources can be stored at zero level of interest rate which could be a way for banks to escape from negative interest rate environment as well. Therefore, a new act or a revisiting of previous regulation should include elimination of the zero interest rate guarantee on free excess reserves of private banks in CNB. Both of the previously mentioned obstacles should be eliminated at ones in order to avoid possible arbitrage opportunity.

Furthermore, a specific issue related to debt contracts could also have unintended consequence. If a nominal amount of debt is repaid in paper notes and coins in the period when currency is away from par (meaning more than one paper Euro is equivalent to one electronic Euro) it would imply that the debtor pays lower sum of money in real terms as the transaction is in nominal cash terms. This peculiarity would need to be reviewed closely if interest rates drop to very negative values when potential gains from similar transactions start to be significant. Currently, debt contracts are regulated in the New Civil Code (Česko 2012). The §2396 states that the repayment of debt, as well as all interests, should be denominated in the same currency as the one that the means were provided in, albeit, the form of currency is not defined. In order to avoid the latter described problem of benefiting from the depreciated value of paper currency, all debt contracts should have the repayment method of the sum owed clearly specified and set to be electronically transferred. Another solution would suggest to denominate all sums owed in terms of electronic money in debt contracts.

Finally, excessive tax prepayments are also a point to be considered in identifying all possible obstacles for the NIRP. If the sum of regular prepayments cut of monthly earnings is higher than the final portion that should be paid on the aggregate yearly earnings (after accounting for tax bonuses and discounts and considering the amount of prepayments is calculated based on previous period tax liability), the taxpayer is entitled to receive the amount overpaid back as stated in the Act No. 586/1992 Coll. on income taxes. In the period of negative interest rates, this would result in an opportunity to store money temporarily at the account of taxpaying authority as the taxpayer would have

the prepayments repaid back with zero interest assuming all time limits for payments were abided by. The system of prepayments should be thus rethought in order to avoid the bypass of the NIRP.

Till now, the analysis was centred around specificities of current legislation that could either confuse interpretations of legal acts or allow for circumvention of the policy. The study will continue by discussing the necessary steps to not only decrease the level of policy rates below zero but also make them significantly negative if there is a need to do so. As discussed earlier, change in paper currency treatment is the crucial component of the strategy.

5.3 Execution of the ZLB elimination strategy

5.3.1 Time varying deposit fee

One of the two main steps of the solution discussed in Chapter 4 is the introduction of the “time-varying paper deposit fee” on all deposits of private banks at a central bank. The first step is to review the capability of the CNB to set specific policy rates in order to conclude whether a fourth policy rate corresponding to the exchange rate between paper and electronic currency could be established and set by the CNB. For instance, Switzerland also needed to consider new legal base for compensations on reserves deposited in the central bank, moreover, they established a threshold up to which reserves are not interest-bearing (Bech & Malkhozov 2016). Following this example, the precedence suggests it is theoretically feasible to set clear framework on interest rates levied on reserves at a central bank, i.e. at the CNB as well. The § 23 of Act No. 227/2013 Coll., that changes the Act 6/1993 on the Czech National Bank states that the CNB can define levels of interest rates, frameworks, deadlines and other conditions related to transaction occurring between the CNB and external stakeholders (Česko 2013). The formulation does not contain specific enumeration of the rates, consequently a fourth policy rate could be incorporated and announced regularly together with discount, repo and lombard 2T rates in order to adjust paper currency value to the trends of electronic money affected by 3 traditional rates. On the top of that, there is not a legal obstacle of setting a limit up to which it would be allowed to store reserves of private banks free of interest so the CNB could also consider to adapt framework to political and monetary needs.

5.3.2 Electronic currency set as the main unit of account

The second step in the strategy of well-functioning negative interest rates is the denomination of prices in terms of electronic money. Article 4, §13 of the Act No. 227/2013 Coll., that changes the Act 6/1993 on the Czech National Bank (Česko 2013) specifies its official currency as the main unit of account. Current formulation establishes the Czech Crown (CZK)~ Koruna česká (Kč - official name and abbreviation in the Czech language) to be the main unit of account in the Czech Republic. §14 and §15 additionally attribute the responsibility over securing, printing and supplying banknotes and coins into the system also to the CNB (Česko 2013).

Presently, neither physical (paper) nor virtual nature of the unit of account is explicitly required as primary by the Czech law. Following the strategy of eliminating the ZLB, it would be, however, advantageous to set electronic form of money as the main unit of account as a supporting mechanism in avoiding cash hoardings after interest rates become negative. The execution could be done by updating the current text of the Act No. 227/2013 Coll., that changes the Act 6/1993 with regard to considering electronic currency as the principal account unit.

Moreover, current technical readiness of the Czech Republic to adopt electronic money as the main unit of account has been strengthening for several years. The number of Point of Sales (POS) terminals was raised by significant 41.25% in 2015 (European Central Bank-Statistical Data Warehouse²). This sharp increase could be partially caused by the preparation of the industry for recently adopted Act No. 112/2016 Coll. (Česko 2016) concerning electronic records of sales of goods and services (e-sales) as well. This act could be seen as an additional step towards less-cash based payment system in the Czech Republic even though this idea was not the primary goal of the legislation. The legislation serves at setting the framework for real time communication between Financial Administration of the Czech Republic and individual entrepreneurs in order to prevent any attempt of tax evasion or other forms of frauds. However, as a side effect, this legislation required the majority of even small businesses that had not possessed an internet access before to be equipped with internet connection to comply with the regulation and clearly, internet access is a crucial assumption in POS terminal payments availability.

Furthermore, inspiration in the process of converting to electronic money

²series key PSS.A.CZ.S102.I00.I200NT.X0.20.Z0Z.Z

prevalence can be taken from ideas of national digital currencies arising for some time in Europe. Sweden is now considering to introduce “e-krona” as a complementary currency (Sveriges Riksbank 2017). The National Bank of Sweden demonstrates in the published report that the trend towards cashless economy both via significant drop in cash purchases and technological advancements of the payments systems is clear (Portion of cash transactions in Sweden fell to merely 15% in 2016 (Sveriges Riksbank 2017)) and thus considers vital to conduct in-depth study in the field. Moreover, Bordo & Levin (2017) highlight advantages of a potential central bank digital currency in the role of the unit of account such as security, stability and low costs. There are, therefore, tendencies to investigate the possibility of digital currency further and in relation with potential necessity of the NIRP, it could be interesting for the CNB to join this wave of considerations.

Psychological effects

An important factor that could thwart the plan to introduce negative interest rates is the perception of cash in the Czech Republic which still belongs to a cluster of European economies with relatively high paper currency usage (only 30.7% of total number of transactions in 2016 were carried via POS terminals ³, while in terms of value, transactions at POS terminals accounted for 34.1% of the total value of transactions ⁴ (ECB Data Warehouse 2017)). However, strong trust towards contactless payments (77.6% of all card transactions employed contactless approach (pro bankovní karty 2016)) could be a sign of potential rising trend in credit and debit card payments.

If the importance of cash transactions remains, the policy of cash depreciation could be communicated as a bonus on withdrawing money instead of paying larger amount than par value on depositing money. The action of withdrawing cash is much more often used as paper cash deposits in a bank are rare due to electronic payment of wages. Economic agents would receive a slightly higher nominal amount of money when withdrawing cash (equivalent to the exchange rate between electronic and paper currency on that specific date) which is psychologically more acceptable than paying additional fees. At first, it would seem that cash payments should be favoured, nevertheless, it would be expected that shops or firms will soon limit paper currency acceptance to

³Comparative Tables - 7.2 Relative importance of payment services

⁴General Notes Czech Republic - 8b. Payments per type of terminal involving non-MFIs, page 1, excluding e-money transactions

avoid bearing additional fees when depositing money in a bank as soon as the rates fall into significantly negative territory.

Additionally, the CNB could establish a guaranteed level of reserves on accounts of private banks that would be exempt from negative interest rate. It could set up a framework in which each client would have a right for one bank account where storage for resources up to the median wage in the economy would be provided free of interest. Therefore, each private bank would be allowed to hold reserves at the CNB equivalent to *median_wage*number_of_clients* that declare holding this specific account with the bank without bearing negative interest rate. This measure could help to improve political acceptability of the NIRP as the least earning group of clients would be excluded from the direct effect while major portion of deposits would still undergo the policy.

5.3.3 Action plan for the CNB

It is, however, not absolutely necessary to undergo all the steps described in the previous chapter immediately and at once. Similarly to Switzerland, Sweden, Euro Area and Denmark that are currently performing a mild version of the NIRP without a necessity to decrease the value of paper currency, the Czech Republic could also first decrease its policy rates only slightly to benefit from all positive aspects that have already been discussed. As Kolcunová (2017) argues, the effective lower bound on interest rate lies in the range of -1% and -2%, it is expected that decreasing the rates to those levels would not require all the strategy related to the ZLB elimination, however, a review of the highlighted legislation and traps arising with the negative value of the reference rate itself is suggested and invited for consideration.

Nevertheless, the proposed solution is of crucial importance for modest negative rates as well. The logic resembles the case of forward guidance, the success of which is strictly dependent on clear and credible communication of the policy to the public by the central bank. In the case of the NIRP, the credibility of the policy is of high importance as the economic agents need to believe the rates can decrease further so that they adjust their behaviour respectively. If they believe the rates have reached the lower bound, they could tend to act as the negative values are only temporary, thus, the transmission is likely not to be complete. Therefore, it is vital to communicate very clearly how it would be possible to decrease rates below the binding level even though the current situation would not require the evasive implementation.

Executing the suggested strategy, the CNB should be prepared to act quickly in case of crises and to decrease the rates below the level of the effective lower bound by making cash holdings equally inconvenient. The legislative changes as well as the introduction of the exchange rate between paper and electronic currency by establishing the fourth reference rate would be needed to ensure effectiveness of the NIRP.

Chapter 6

Conclusion

This bachelor thesis provides insights into practical implementation of the NIRP in the context of the Czech Republic. The text constitutes the first overview of possible challenges that could be faced by the CNB related to the introduction of negative interest rates, an unconventional monetary policy that is currently subject to many discussions. The main contribution of the thesis lies in gathering both legal and practical obstacles that would need to be eliminated once the CNB decides to adopt the policy of decreasing main policy interest rates below zero level, or possibly even lower. It completes the discussions about appropriateness and feasibility of the NIRP approach for the specific case of the Czech Republic. Moreover, it offers a guide for the CNB explaining the strategy to follow concerning the policy.

In order to draw a complete conclusion and recommendation on the matter for the Czech Republic, the thesis starts by an empirical study employing VAR model analysis on the data of countries experienced in the NIRP. A thorough approach to the exercise needed to be taken as the data availability is very limited, the first introduction of the policy happening in July 2012 only (monthly data available). Nevertheless, I proceeded with empirical work to provide first data based research of the interest rate transmission mechanism on the most recent data. Impulse response functions of a one standard deviation shock to interest rate into macroeconomic variables (GDP, HICP, IR) are presented, however, results are not statistically significant for most of the cases. Moreover, extracting some indicative results only, responses do not seem to demonstrate a well-functioning transmission. The reasons for this nature of results could lie either in the limitations of the model, caused by data restrictions or in the imperfections of the transmission resulting from defective mechanism of the

NIRP under an unclear plan of significantly lower rates introduction. In order to eliminate this potential problem related to the lack of strength in the communication channel accompanying the NIRP, developing the strategy of the ZLB elimination appeared even more urgent.

The text elaborates a comprehensive explanation of the method to eliminate the binding ZLB. This bound threatens the functionality of the NIRP based on the fact that the possibility to convert bank deposits bearing negative interest into cash paying guaranteed zero interest rate still exists. Ideas proposed by Buiter (2009); Agarwal & Kimball (2015); Rogoff (2017) are combined synthesizing the main required steps for central bankers. The solution is composed (i) of establishing electronic money to become the main unit of account; and (ii) of introducing a time-varying exchange rate between electronic currency and paper currency to avoid excessive cash holdings and thus to ensure effective transmission of the rates into the economy.

Case Study Research (CSR) is performed to come up with all potential complications that the CNB would need to face in the process of implementing the NIRP. It was identified that free reserves of private banks kept at the CNB on the top of the required reserves do not earn any interest, moreover, excessive tax prepayments are returned to the taxpayer at nominal value without being subject to negative interest rates in the meantime. Both of these facts could be abused to avoid NIRP regime. Furthermore, zero interests levied on the accounts of government and public organisations as well as the possibility of repaying debt in paper notes with decreased value would entail situations with unlawful advantages for the participants. Additionally, an important and valuable part of the study concentrates on enumerating and briefly describing acts of the Czech legal system that would suffer from misinterpretations in the period of negative reference rates for the reason of predefined traditional understanding of the word *interest* to be positive.

The Czech Republic is recommended to prepare for the potential need of introducing negative interest rates by reviewing its legislation and procedures highlighted in the case study. Without judging on positive or negative effects of the NIRP, abundant literature and recent experience suggest that it is crucial to adjust the system for this possibility (Cœuré 2012; Fischer 2016). In order to extend the scope of the thesis further, Panel VAR model or Bayesian VAR model could be elaborated to allow for clearer investigation of the transmission mechanism under slight negative rates.

Bibliography

- (2017): “Nařízení vlády č. 434/2017 ze dne 29. listopadu 2017, kterým se mění nařízení vlády č. 351/2013 Sb., kterým se určuje výše úroků z prodlení a nákladů spojených s uplatněním pohledávky.” .
- AGARWAL, R. & M. S. KIMBALL (2015): “Breaking Through the Zero Lower Bound.” *IMF Working Paper* **15/224**.
- ALQAHTANI, F. H. (2017): “Developing an Information Security Policy: A Case Study Approach.” *Procedia Computer Science* **124**: pp. 691–697.
- ARTETA, C., M. A. KOSE, M. STOCKER, & T. TASKIN (2018): “Implications of negative interest rate policies: An early assessment.” *Pacific Economic Review* **23(1)**: pp. 8–26.
- BÄURLE, G. & D. KAUFMANN (2014): “Exchange Rate and Price Dynamics in a Small Open Economy - The Role of the Zero Lower Bound and Monetary Policy Regimes.” *SNB Working Papers* (**10**).
- BECH, M. & A. MALKHOZOV (2016): “How have central banks implemented negative policy rates?” *BIS Quarterly review* (**March**): pp. 31–44.
- BERNANKE, B. (2013): “The Federal Open Market Committee Press Conference.” *Press Conference from March 20, 2013* .
- BINNING, A. & H. C. BJØRNLAND (2017): “Is Monetary Policy Always Effective? Incomplete Interest Rate Pass-through in a DSGE Model*.” *Centre for Economic Policy Research - Preliminary Version* (**1**).
- BLANCHARD, O., G. DELL’ARICCIA, & P. MAURO (2010): “Rethinking macroeconomic policy.” *Journal of Money, Credit and Banking* **42(1)**: pp. 199–215.

- BORDO, M. D. & A. T. LEVIN (2017): “Central Bank Digital Currency and the Future of Monetary Policy.” *Nber Working Paper Series* **23711**.
- BROOKS, C. (2008): *Introductory Economics fo Finance*. Cambridge : Cambridge University Press.
- BRUNNERMEIER, M. K., Y. KOBAYASHI, & M. KOBAYASHI (2017): “The Reversal Interest Rate; : An Effective Lower Bound on Monetary Policy.” *Working Paper Princeton University* pp. 1–27.
- BUITER, W. (2015a): “It’s Time to Remove the Lower Bound on Interest Rates and Here’s the How To. Why do we need to get rid of the ELB ?” *Citi Bank Research* pp. 1–24.
- BUITER, W. H. (2005): “Overcoming the zero bound on nominal interest rates: Gesell’s currency carry tax vs. Eisler’s parallel virtual currency. Discussion of Mitsuhiro Fukao’s ”The effects of ’Gesell’ (currency) taxes in promoting Japan’s economic recovery”.” *International Economics and Economic Policy* **2(2-3)**: pp. 189–200.
- BUITER, W. H. (2009): “Negative nominal interest rates: Three ways to overcome the zero lower bound.” *North American Journal of Economics and Finance* **20(3)**: pp. 213–238.
- BUITER, W. H. (2014): “The simple analytics of helicopter money: Why it works - Always.” *Economics* **8(1)**: pp. 1–46.
- BUITER, W. H. (2015b): “It’s Time to Remove the Lower Bound on Interest Rates and Here’s the How-To.” In “’Removing the Zero Lower Bound on Interest Rates’ Brevan Howard Centre for Financial Analysis Imperial College Business School CEPR & Swiss National Bank Event,” .
- BUITER, W. H. & N. PANIGIRTZOGLU (2003): “Overcoming the Zero Bound on Nominal Interest Rates with Negative Interest on Currency : Gesell ’s Solution.” *The Economic Journal* **113(490)**: pp. 723–746.
- BURGSTALLER, J. (2005): “Interest Rate Pass-Through Estimates From Vector Autoregressive Models.” *Johannes Kepler University of Linz Department of Economics Working Paper* **0510**.

- CALDENTEY, E. P. (2017): “Quantitative Easing , Changes in Global Liquidity and Financial Instability.” *International Journal of Political Economy* (**46, February**): pp. 91–112.
- ČESKO (2012): “Zákon č. 89/2012 Sb. ze dne 3. února 2012, občanský zákoník.” *Sbírka zákonů České republiky* .
- ČESKO (2013): “Zákon č. 227/2013 Sb. ze dne 20. června 2013, kterým se mění zákon č. 6/1993 Sb., o České národní bance, ve znění pozdějších předpisů, a další související zákony.” *Sbírka zákonů České republiky* .
- ČESKO (2016): “Zákon č. 112 / 2016 Sb. ze dne 16. března 2016, o evidenci tržeb.” *Sbírka zákonů České republiky* .
- CHATTOPADHYAY, S. & T. GHOSH (2016): “Cost Channel, Interest Rate Pass-Through and Optimal Monetary Policy under Zero Lower Bound.” *MPRA Paper 72762, University Library of Munich, Germany* (**July**).
- CNB (2016): “Úřední sdělení české národní banky č. 21016610 ze dne 31. 10. 2016.” .
- CNB (2018): “Podmínky České národní banky pro vedení účtů právníky osobám a provádění platebního styku (1.5.2018).” .
- CŒURÉ, B. (2012): “Central banks and the challenges of the zero lower bound.” In “Meeting on the Financial Crisis hosted by the Initiative on Global Markets, at the University of Chicago Booth School of Business, Miami, 19 February 2012,” .
- ECB (2014a): *Annual Report 2014*. June.
- ECB (2014b): “Decision of the European Central Bank of 20 February 2014 on the prohibition of monetary financing and the remuneration of government deposits by national central banks (ECB/2014/8).”
- ECB DATA WAREHOUSE (2017): “ECB Payment Statistics, General Report.”
- EISLER, R. (1932): *Stable Money, The Remedy of Economic World Crisis*. The Search Publishing Co. Ltd.
- FISCHER, S. (2016): “Monetary Policy, Financial Stability, and the Zero Lower Bound.” In “Annual Meeting of the American Economic Association,” .

- FISHER, I. (1896): "Appreciation and Interest." *American Economic Association* **11**(4): pp. 331–442.
- FRANTA, M. C. (2014): "The Exchange Rate as an Instrument at Zero Interest Rates: The Case of the Czech Republic." *Research and Policy Notes* **3**(September): p. 52.
- FUKAO, M. (2005): "The effects of 'Gesell' (currency) taxes in promoting Japan's economic recovery." *International Economics and Economic Policy* **2**(2-3): pp. 173–188.
- GERRING, J. (2017): *Case study research: principles and practices*. Cambridge University Press.
- GESELL, S. (1916): "The Natural Economic Order." *Peter Owen Ltd* (**translated by Philip Pye, London 1958**).
- GEVA-MAY, I. (2005): "Case Study Method and Policy Analysis." In "Thinking Like a Policy Analyst," Palgrave Macmillan, New York.
- GOODFRIEND, M. (2000): "Overcoming the Zero Bound on Interest Rate Policy." *Journal of Money, Credit and Banking* .
- GOODFRIEND, M. (2015): "Overcoming the Zero Bound with Negative Interest Rate Policy." In "Removing the Zero Lower Bound on Interest Rates, An Imperial College Business School, Brevan Howard Centre for Financial Analysis, CEPR, and Swiss National Bank Event," May.
- GRISSE, C. & S. SCHUMACHER (2017): "The response of long-term yields to negative interest rates: evidence from Switzerland." *Swiss National Bank Working Papers* .
- HÁLOVÁ, K. (2015): "The Impact of Unconventional Monetary Policy of ECB to Central and Eastern European Countries: A Panel VAR Analysis." *Master's Thesis Charles University in Prague* .
- HAMPL, M. & T. HAVRANEK (2018): "Central Bank Capital as an Instrument of Monetary Policy." *Working Paper available at <http://hdl.handle.net/10419/176828>* .
- HAVRÁNEK, T., R. HORVÁTH, & J. MATĚJŮ (2012): "Monetary transmission and the financial sector in the Czech Republic." *Economic Change and Restructuring* **45**(3): pp. 135–155.

- HEIDER, F., F. SAIDI, & G. SCHEPENS (2017): "Life Below Zero: Bank Lending Under Negative Policy Rates." *SSRN Electronic Journal*. Available at <https://ssrn.com/abstract=2788204> .
- HICK'S, J. R. (1937): "Mr. Keynes and the "Classics": a suggested interpretation." *Econometrica* **5(2)**: pp. 147–159.
- HORVATH, R., J. KOTLEBOVA, & M. SIRANOVA (2018): "Interest rate pass-through in the euro area: Financial fragmentation, balance sheet policies and negative rates." *Journal of Financial Stability* **36**: pp. 12–21.
- IMF (2017): "Negative Interest Rates Policies- Initial Experiences and Assessments." *IMF Policy Papers* .
- IVANOV, V. & L. KILIAN (2005): "A Practitioner's Guide to Lag Order Selection For VAR Impulse Response Analysis." *Studies in Nonlinear Dynamics & Econometrics* **9(1)**.
- JENSEN, C. M. & M. SPANGE (2015): "Interest Rate Pass- Through and the Demand for Cash At Negative Interest Rates." *Danmarks nationalbank monetary review 2* pp. 55–66.
- JOBST, A. & H. LIN (2016): "Negative Interest Rate Policy (NIRP): Implications for Monetary Transmission and Bank Profitability in the Euro Area." *IMF Working Paper (172)*: pp. 1–48.
- PRO BANKOVNÍ KARTY, S. (2016): "Souhrnná statistika SBK za 2016." *Technical report*.
- KEYNES, J. M. (1936): *The General Theory of Employment, Interest And Money*. Macmillan.
- KHAYAT, G. A. (2018): "The impact of setting negative policy rates on banking flows and exchange rates." *Economic Modelling* **68(May 2016)**: pp. 1–10.
- KILEY, M. T. & J. M. ROBERTS (2017): "Monetary Policy in a Low Interest Rate World." *Brookings Papers on Economic Activity* **Fall**: pp. 317–396.
- KOLCUNOVÁ, D. (2017): "Estimating the Effective Lower Bound for the Czech National Bank's Policy Rate." *Master's Thesis Charles University in Prague* .

- KUMAKURA, M. (2016): “Japan ’ s Monetary Policy Misadventure.” *World Economics* **17**(2).
- LUTKEPOHL, H. (2006): *New introduction to multiple time series analysis*, volume 1. Springer.
- MISHRA, P. & P. MONTIEL (2012): “How Effective is Monetary Transmission in Low-Income Countries? A Survey of the Empirical Evidence.” *IMF Working Papers* **12**(143).
- MOJON, B. & G. PEERSMAN (2001): “A VAR description of the effects of monetary policy in individual countris of the Euro Area.” *ECB working paper* (no. 92).
- NAKAJIMA, J. (2011): “Monetary Policy Transmission under Zero Interest Rates : An Extended Time-Varying Parameter Vector Autoregression Approach.” *IMES Discussion Paper Series 11-E-08, Institute for Monetary and Economic Studies, Bank of Japan*. **11**(1).
- PFFAF, B. (2008): *Analysis of Integrated and Cointegrated Time Series with R*. Springer.
- RACHEL, L. & T. D. SMITH (2017): “Are low real interest rates here to stay?” *International Journal of Central Banking* **13**(3): pp. 1–42.
- REIFSCHNEIDER, D. & J. C. WILLIAMS (1999): “Three Lessons for Monetary Policy in a Low Inflation Era.” *Jounral of Money, Credit and Banking* **32**: pp. 936–966.
- REMENYI, D. (2013): *Case study research*. Reading : Academic Conferences and Publishing International Limited.
- RODNYANSKY, A. & O. M. DARMOUNI (2017): “The effects of quantitative easing on bank lending behavior.” *Review of Financial Studies* **30**(11): pp. 3858–3887.
- ROGOFF, K. (2017): “Dealing with Monetary Paralysis at the Zero Bound.” *Journal of Economic Perspectives* **31**(3 - Summer): pp. 47–66.
- ROGOFF, K. S. (2016): *The Curse of Cash*. Princeton University Press.

- SABOROWSKI, C. & S. WEBER (2013): "Assessing the Determinants of Interest Rate Transmission Through Conditional Impulse Response Functions." *Journal of Chemical Information and Modeling* **(January)**.
- SUMMERS, L. H. (2014): "U.S. economic prospects: Secular stagnation, hysteresis, and the zero lower bound." *Business Economics* **49(2)**: pp. 65–73.
- SVENSSON, L. E. O. (2000): "The Zero Bound in an Open Economy: A Foolproof Way of Escaping from a Liquidity Trap." *National Bureau of Economic Research Working Paper Series No. 7957(February)*: pp. 277–322.
- SVERIGES RIKSBANK (2017): "The Riksbank's e-krona project." **(September)**: p. 44.
- TURK, R. A. (2016): "Negative Interest Rates : How Big a Challenge for Large Danish and Swedish Banks?" *IMF Working Papers* pp. 1–29.
- WILLIAMS, J. C. (2013): "A Defense of Moderation in Monetary Policy A Defense of Moderation in Monetary Policy." *Federal Reserve Bank of San Francisco Working Papers* **(July)**.
- WILLIAMS, J. C. (2014): "Monetary Policy at the Zero Lower Bound: Putting Theory into Practice." *Hutchins Center on Fiscal & Monetary Policy: Brookings* pp. 1–20.
- WILLIAMSON, S. D. (2017): "Low Real Interest Rates and the Zero Lower Bound." *Working Paper 2017-010A* <https://doi.org/10.20955/wp.2017.010>.
- WITMER, J. & J. YANG (2016): "Estimating Canada's Effective Lower Bound." *Bank of Canada Review* **(Spring)**: pp. 3–14.
- WOODFORD, M. & G. EGGERTSSON (2003): "The Zero Bound on Interest Rates and Optimal." *Brookings Papers on Economic Activity* **(1)**: pp. 139–211.
- WOODSIDE, A. G. (2010): *Case Study Research: Theory, Methods and Practice*. Emerald Publishing Limited.
- WOODSIDE, A. G., H. PATTINSON, & R. MARSHALL (2014): *Field Guide to Case Study Research in Business-to-Business Marketing and Purchasing*. Emerald Publishing Limited.

WOOLDRIDGE, J. M. (2012): *Introductory Econometrics : a Modern Approach*.
Mason, Ohio: South-Western Cengage Learning.

YIN, R. K. (2014): *Case study research: design and methods*. Los Angeles:
Sage.

Appendix A

Complementary material

Table A.1: Stationarity tests

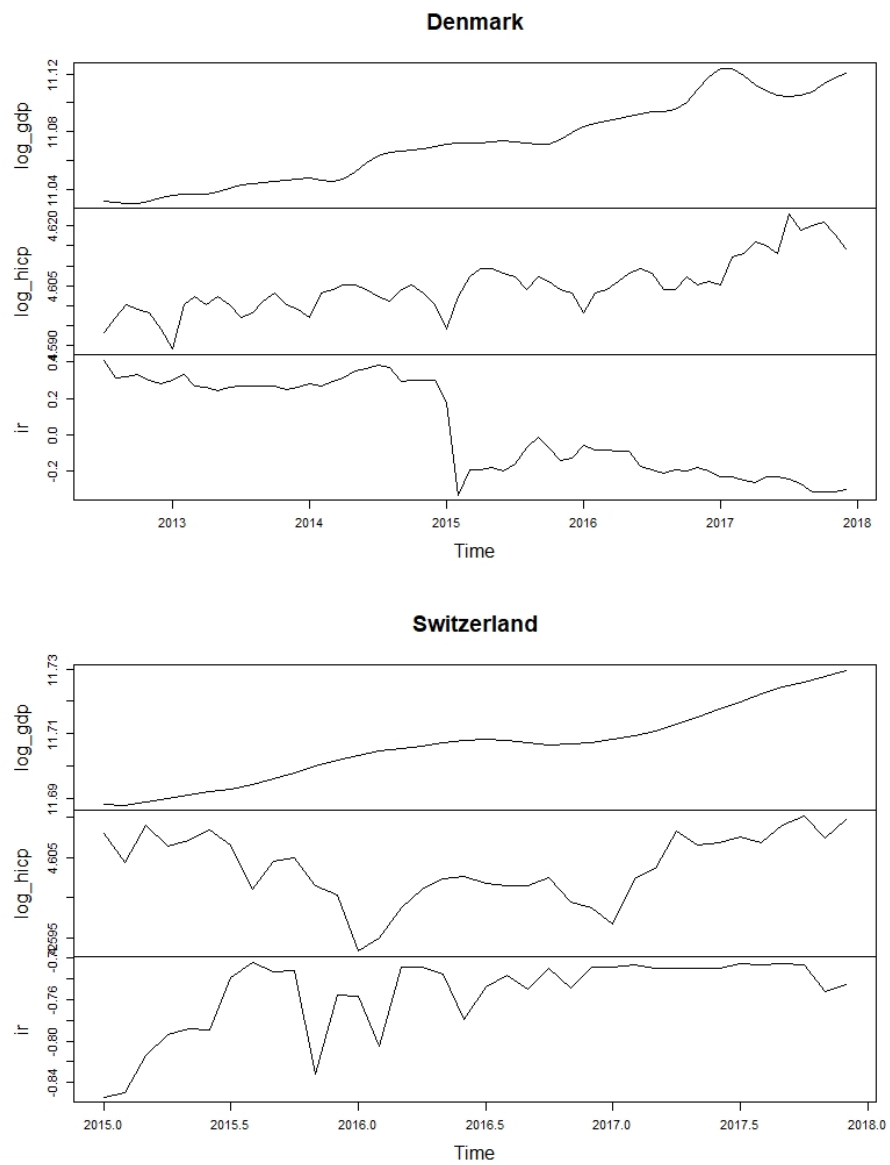
Augmented Dicky-Fuller test						
non-differenced				differenced		
p-values	log_GDP	log_HICP	level_IR	dlog_GDP	dlog_HICP	dlevel_IR
Denmark	0.04	0.14	0.39	0.03	0.01	0.01
Switzerland	0.07	0.73	0.08	0.38	0.02	0.01
Sweden	0.70	0.76	0.66	0.33	0.01	0.23
Euro Area	0.77	0.52	0.77	0.44	0.01	0.01
Perron-Phillips test						
non-differenced				differenced		
p-values	log_GDP	log_HICP	level_IR	dlog_GDP	dlog_HICP	dlevel_IR
Denmark	0.25	0.01	0.28	0.01	0.01	0.01
Switzerland	0.93	0.60	0.04	0.32	0.01	0.01
Sweden	0.90	0.10	0.98	0.07	0.01	0.01
Euro Area	0.73	0.08	0.96	0.19	0.01	0.01

Dicky-Fuller test performed considering 3 lags, both tests employed with drift and trend for non-differenced data, with drift and without trend for differenced data;

p-value = 0.01 means $p\text{-value} \leq 0.01$

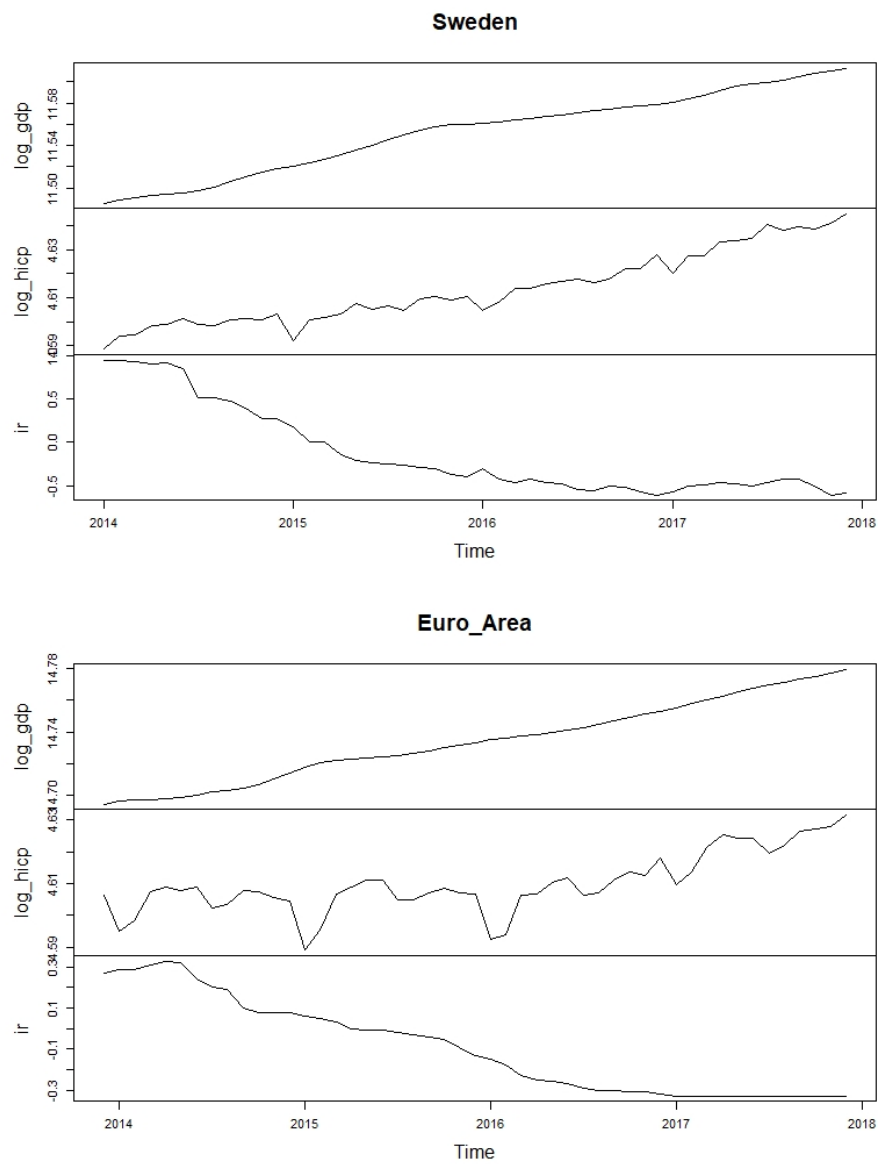
Source: Author's calculations

Figure A.1: Data Visualization: Denmark and Switzerland



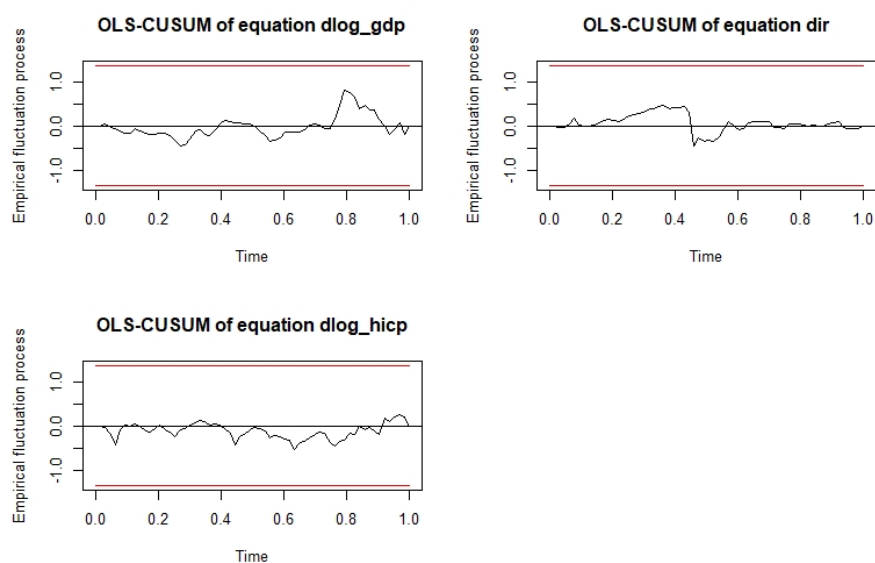
Source: Eurostat, Database of the Swiss National Bank

Figure A.2: Data Visualisation: Sweden and the Euro Area



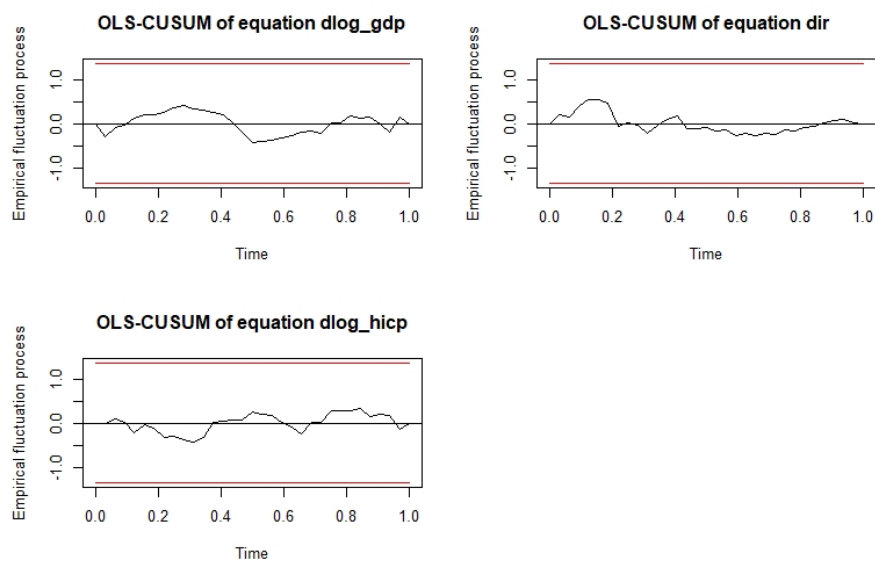
Source: Eurostat

Figure A.3: Stability test - OLS - CUSUM - Denmark



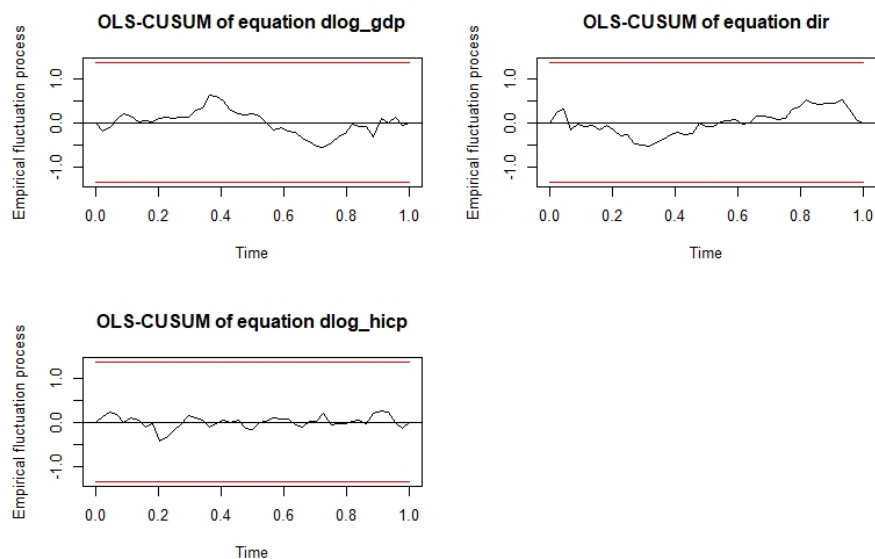
Source: Author's calculations

Figure A.4: Stability test - OLS - CUSUM - Switzerland



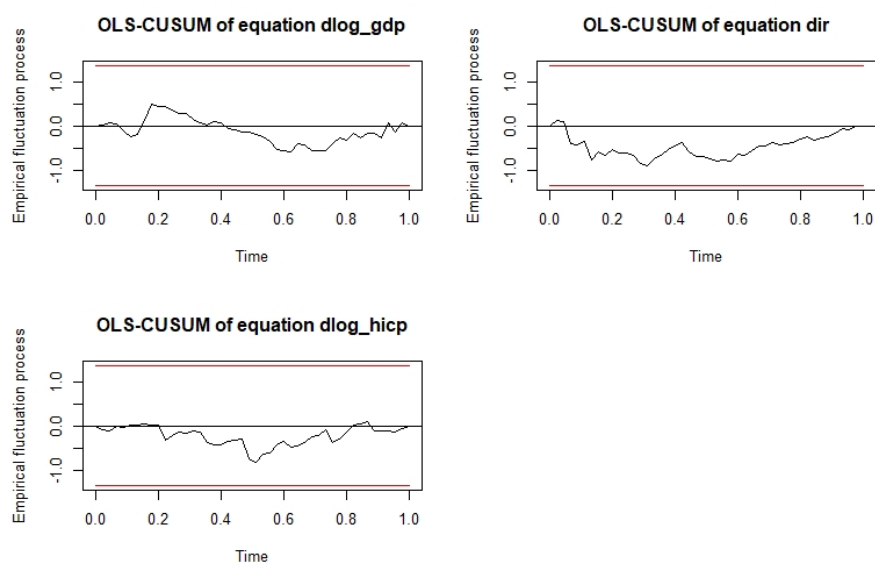
Source: Author's calculations

Figure A.5: Stability test - OLS - CUSUM - Sweden



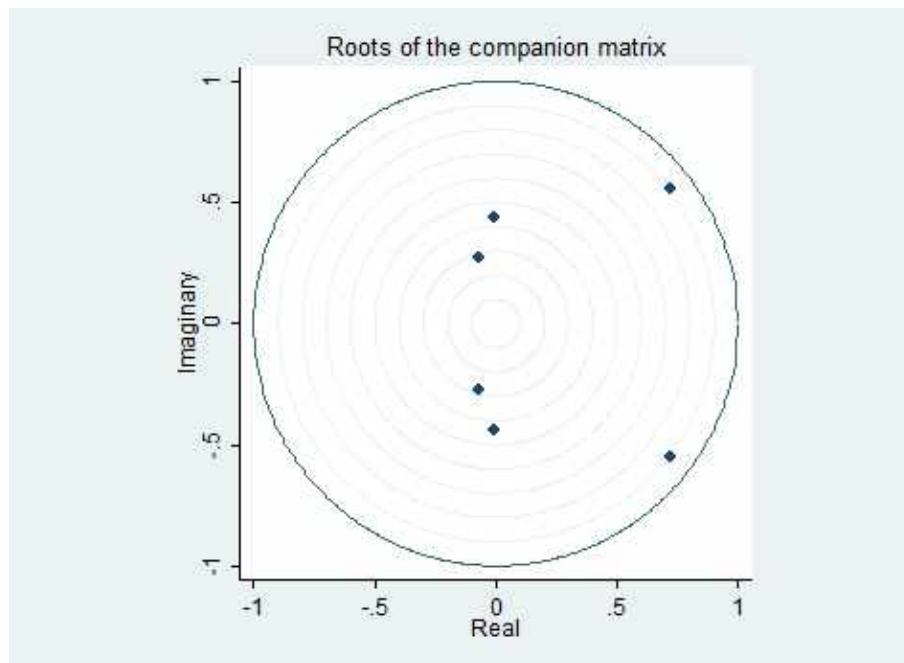
Source: Author's calculations

Figure A.6: Stability test - OLS - CUSUM - Euro Area



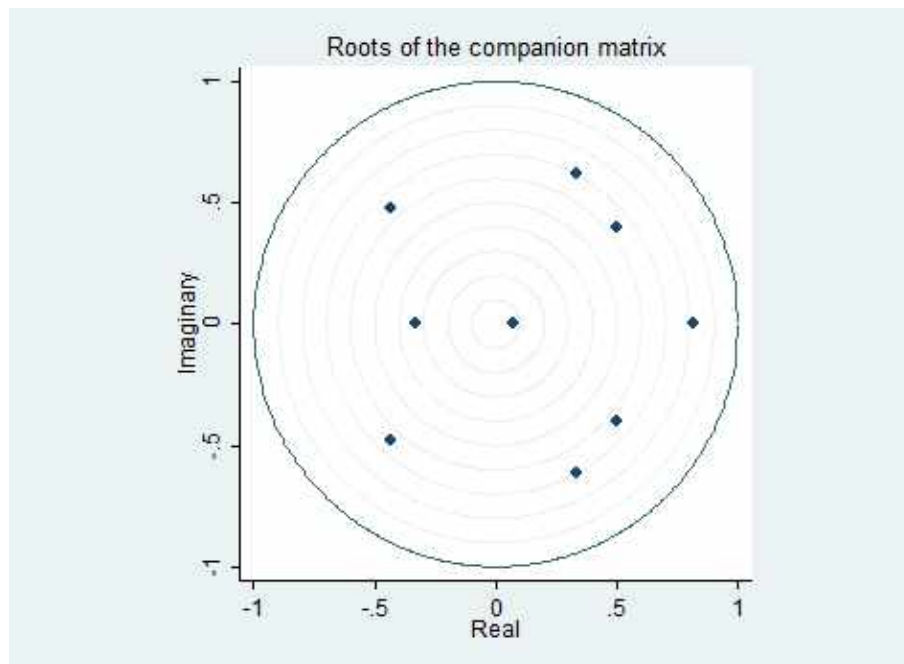
Source: Author's calculations

Figure A.7: Stability condition - Denmark



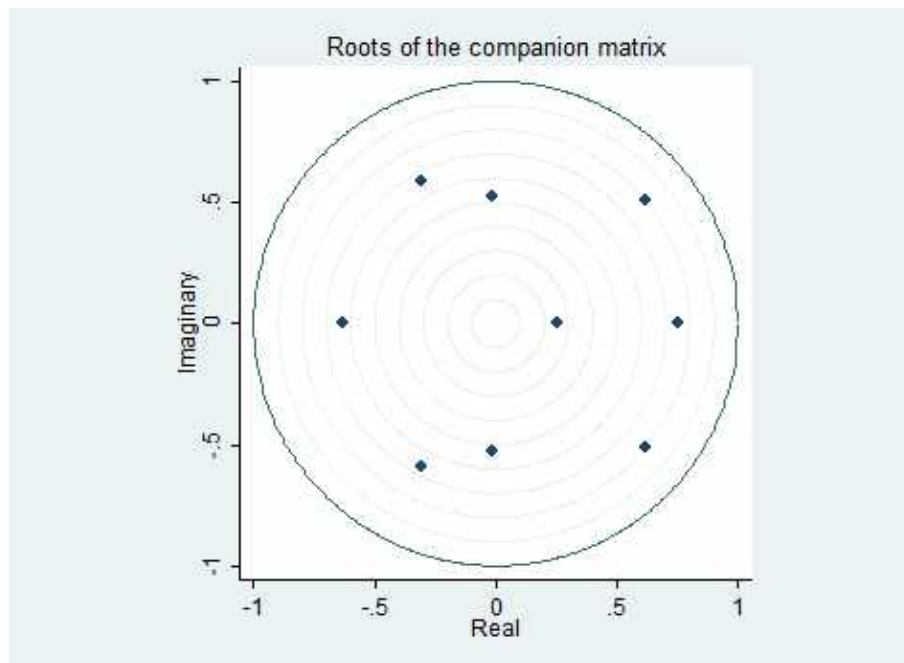
Source: Author's calculations

Figure A.8: Stability condition - Switzerland



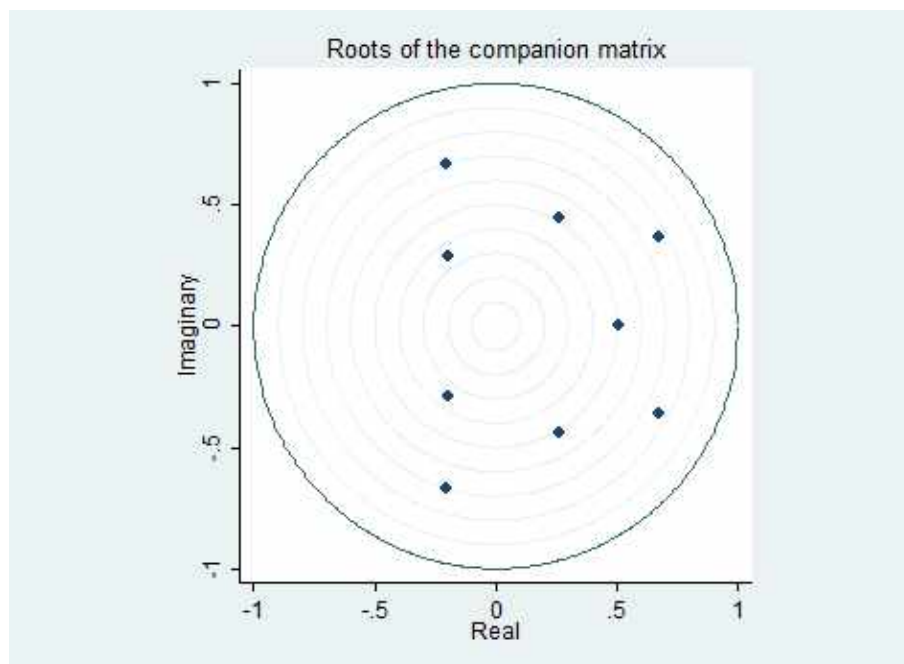
Source: Author's calculations

Figure A.9: Stability condition - Sweden



Source: Author's calculations

Figure A.10: Stability condition - Euro Area



Source: Author's calculations