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Anwar Khayat

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Abstract

Setting negative nominal rates is one of the unconventional policies implemented after the Great Recession to overcome the Zero Lower Bound. Using data from the euro area and Denmark, I assess the impact of introducing a negative interest rate on reserves. I find that it did put a depreciation pressure on the currency due to a reversal in banking flows. This effect is not only caused by policy differentials, but also by a distinct impact of going into negative territory from lowering interest rates.

Keywords: Monetary Policy; Negative Nominal Rates; Exchange Rates; Banking Flows

JEL Classification Numbers: E52, E58, F31

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Introduction

After Japan's experience since the 1990s, the risk of a binding Zero Lower Bound (ZLB) stimulated a reconsideration of monetary policy transmission channels. On the one hand, Krugman (1998) suggests a credible promise from the central bank that it will not raise policy rates when the economy expands and prices begin to rise. Both McCallum (2000) and Svensson (2000b) suggest policies based on a depreciation of the exchange rate. On the other hand and despite a renewed interest, negative nominal interest rates were widely considered as unrealistic until the Great Recession.

Negative nominal rates are one of the unconventional policies implemented after the Great Recession by several central banks to overcome the ZLB. Danmarks Nationalbank (the Danish National Bank; July 5th 2012) was the first to implement a negative interest rate on reserves¹. Since then, the European Central Bank (ECB; June 5th 2014), the Sveriges Riksbank (the Bank of Sweden; October 27th 2014) and the Swiss National Bank (December 18th 2014) went into negative territory².

The ZLB is due to the traditional assumption of paying zero interest rate on money. This assumption might be reasonable for currency, but not for commercial banks' reserves at the central bank. Goodfriend (2000) and Blinder (2012) recommend to pay negative interest rate on reserves (a carry tax) to overcome the ZLB. This is technically costless for central banks, but its negative floor would be the storing costs of currency (otherwise commercial banks would store reserves as vault cash).

However, paying a negative interest rate on base money (both currency and reserves) is technically feasible (see Goodfriend, 2000). Buiter and Panigirtzoglou (2003) shows that it is sufficient to avoid and escape a liquidity trap and Buiter (2009) suggests several ways to

¹Sveriges Riksbank set negative interest rate on reserves (its deposit facility) in July 2009, but this was merely technical due to its fine-tuning transactions (see Sellin and Sommar, 2012).

²I consider in this paper the impact of setting negative interest rate on reserves or excess reserves. The Bank of Sweden and the Swiss National Bank have recently introduced negative lending rates which might have an additional impact, but this goes beyond the scope of this paper.

implement it.

Yates (2004) and Ilgmann and Menner (2011) consider that inflation and paying negative interest rate (money *taxes*) are perfect substitutes. Menner (2011) confirms this intuition and shows that, at moderate inflation levels, negative policy rates (*taxing* money) have a positive impact on velocity and the real economy. Finally, McAndrews (2015) argues that negative nominal rates are qualitatively different from positive rates.

To my knowledge, there is no empirical paper among this strand of the literature. I fill this gap by examining the impact of implementing a negative interest rate on reserves. I use data from both the euro area and Denmark.

Furthermore, paying a negative interest rate on reserves did not push retail banking interest rates into negative territory (see Callesen (2013)). This suggests that banks' behavior should be considered closely.

I consider the impact on capital flows, banking flows (through the composition of banks' internal vs. external assets and the composition of banks' assets in foreign currencies vs. Danish krone) and the Taylor-rule fundamentals model of exchange rates.

I estimate Markov Regime Switching with Time Varying Transition Probabilities (MS-TVTP) models with the interest rate paid on reserves as a transition variable to assess potential regime shifts in banking flows and exchange rates.

I find that paying a negative interest rate on reserves did put a depreciation pressure on the currency due to a mild reversal in banking flows. This effect seems to be caused not only by policy differentials, but also by a distinct impact³ of going into negative territory from lowering interest rates.

³Money illusion seems to be the source of this distinct impact. See Shafir et al. (1997), Cohen et al. (2005) and Schmeling and Schrimpf (2011) for evidence on money illusion.

1 Methodology

Both Smooth Transition Regression and Markov Regime Switching are the main models used in the literature to estimate and assess potential regime switching in the data. Both models do not assume any exogenous regime and allow the use of transition variables containing economic information to explain the regime switching.

The shape of the transition assumed by Markov models is more suitable here (deterministic regime switching and both the logistic and exponential transition functions of the STR models do not seem adapted for the analyzed data; see Hamilton, 2005 for a brief introduction to Markov models). Therefore, I estimate Markov Regime Switching with Time Varying Transition Probabilities (MS-TVTP) models, presented briefly below, with the interest rate paid on reserves as a transition variable to assess potential regime shifts.

$$y_t = \alpha(s_t) + X_t' \beta + \epsilon_t$$

where $E(\epsilon_t|X_t) = 0$, $\epsilon_t \sim \mathcal{N}(0, \sigma(s_t))$ and the indicator $s_t \in \{1, 2\}$ which determines the state at time t . The switching dynamics are driven by the following time-varying (which depends on the transition variable) transition matrix:

$$\begin{pmatrix} p_t^{11} & p_t^{12} \\ p_t^{21} & p_t^{22} \end{pmatrix}$$

I assume that only the mean and the variance can switch regimes which allows a direct interpretation of both regimes. If the dependent variable y is a proxy of banking outflows and the estimations show a statistically significant regime switching, the regime related to the highest mean can be considered the high banking outflows regime.

I use Z. Ding's Matlab package (see Ding, 2012 and Perlin, 2010 for more details) to

estimate the MS-TVTP models. Data⁴ is monthly and is collected from Reuters Datastream, the Federal Reserve Economic Data (FRED), the Danmarks Nationalbank's StatBank and the ECB's Statistical Data Warehouse⁵.

I implement Carrasco et al. (2014) to test the hypothesis of linearity against the alternative of a Markov switching model. For all estimations, the null hypothesis of no regime change is strongly rejected in favor of the alternative of two-state Markov-switching models.

1.1 Exchange rates

I follow Chinn (2008) and Rossi (2013) and estimate MS-TVTP exchange rate models based on Taylor rule fundamentals to assess the exchange rate regimes.

Starting from an ad hoc characterization of the exchange rate/interest differential relationship⁶:

$$s_{t+h} - s_t = \kappa(i_{t+h} - i_{t+h}^*)$$

with $\left\{ \begin{array}{l} \kappa < 0 \quad \text{if the home currency is in the numerator of } s \\ \kappa > 0 \quad \text{if the home currency is in the denominator of } s \end{array} \right.$

And assuming that policy makers in both countries (I use asterisks to denote foreign country variables) follow a standard Taylor rule:

$$i_{t+h} = (1 - \rho)(\mu + \lambda\pi_t + \gamma y_t^{gap}) + \rho i_t + \epsilon_{t+h}$$

$$i_{t+h}^* = (1 - \rho^*)(\mu^* + \lambda^*\pi_t^* + \gamma^* y_t^{gap*}) + \rho^* i_t^* + \epsilon_{t+h}^*$$

⁴Database, codes and an appendix describing data transformations are available on <https://sites.google.com/site/anwarkhayat/research>.

⁵I used Lanne et al. (2002) to test for outliers and level shifts, then statistically significant shift dummies were kept in the regressions. See the on line appendix for more details.

⁶I set $h = 3$ to be consistent with the literature which mainly considers models with one quarter ahead.

where π denote the inflation rate, y^{gap} the output gap and i the short term interest rate.

This imply the Taylor-rule fundamentals model of exchange rates:

$$s_{t+h} - s_t = \tilde{\mu} + \tilde{\lambda}\pi_t + \tilde{\lambda}^*\pi_t^* + \tilde{\gamma}y_t^{gap} + \tilde{\gamma}^*y_t^{gap*} + \tilde{\rho}i_t + \tilde{\rho}^*i_t^* + v_{t+h}$$

Despite being controversial, it is also common in the literature to assume that the central bank attempts to stabilize the real exchange rate, q_t , (see Svensson, 2000a and Molodtsova and Papell, 2009):

$$\begin{aligned} i_{t+h} &= (1 - \rho)(\mu + \lambda\pi_t + \gamma y_t^{gap} + \delta q_t) + \rho i_t + \epsilon_{t+h} \\ i_{t+h}^* &= (1 - \rho^*)(\mu^* + \lambda^*\pi_t^* + \gamma^* y_t^{gap*}) + \rho^* i_t^* + \epsilon_{t+h}^* \end{aligned}$$

which implies:

$$s_{t+h} - s_t = \tilde{\mu} + \tilde{\delta}q_t + \tilde{\lambda}\pi_t + \tilde{\lambda}^*\pi_t^* + \tilde{\gamma}y_t^{gap} + \tilde{\gamma}^*y_t^{gap*} + \tilde{\rho}i_t + \tilde{\rho}^*i_t^* + v_{t+h}$$

Finding the exchange rate minus the central rate stationary at 10%, due to the specific framework of the fixed exchange rate regime in Denmark, I also suggest the following smoothed specification which better suits the Danish krone vs. euro exchange rate dynamics:

$$s_{t+h} = \tilde{\mu} + \tilde{\rho}_s s_t + \tilde{\delta}q_t + \tilde{\lambda}\pi_t + \tilde{\lambda}^*\pi_t^* + \tilde{\gamma}y_t^{gap} + \tilde{\gamma}^*y_t^{gap*} + \tilde{\rho}i_t + \tilde{\rho}^*i_t^* + v_{t+h}$$

1.2 Capital and banking flows

I use Foreign reserves minus gold to capture the euro area capital flows⁷. And I use both banks' external (rest of the world) vs. internal net assets and banks' net assets in foreign currencies vs. Danish krone to assess banking flows in Denmark.

⁷To my knowledge, there is no published disaggregated data about banks' balance sheets in the euro area.

I suggest ad hoc specification with the following independent variables in capital and banking flows estimations: home and foreign output gap, home and foreign stock indexes and home and foreign short term interest rates⁸.

2 The euro area

At June 5th 2014, the ECB decided the pay a negative interest rate on reserves (its deposit rate). Figure 1, the shaded zone is the period when the euro area is in negative territory, shows a sharp depreciation of the euro since this decision (more than 15% by the end of 2014).

Did the decision of the ECB to go into negative territory put a depreciation pressure on the euro by impacting capital flows? To answer this question I consider both exchange rate models based on Taylor rule fundamentals and the euro area foreign reserves minus gold.

2.1 The exchange rate

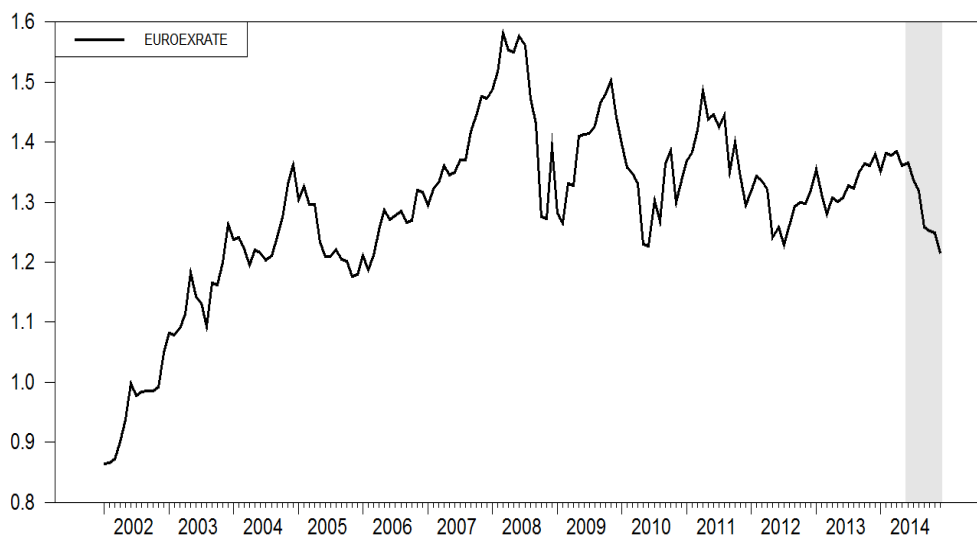


Figure 1: USD vs. Eur exchange rate

⁸The United States is the foreign economy when I assess the impact of going into negative territory in the euro area. And the euro area is the foreign economy when considering Denmark.

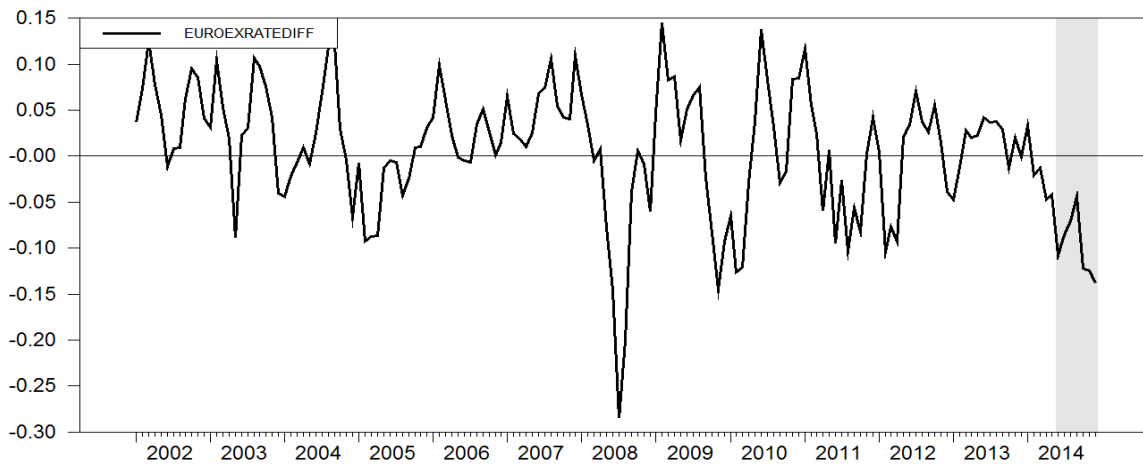
I estimate the Taylor-rule fundamentals model of USD/Eur exchange rate, but I allow both the mean and variance to switch regimes. Results are presented in Table 1, they suggest statistically significant regime switching. At the exception of the short term interest rates, all significant estimations have the expected sign.

Variable	Without Real Exchange Rate				With Real Exchange Rate			
	Estimation	Std-error†			Estimation	Std-error†		
Intercept (state 1)	0.177115	0.136216			0.163323	0.133707		
Intercept (state 2)	-0.847114	0.153384***			-0.894615	0.156394***		
π_t	1.135148	0.536805**			1.15901	0.527669**		
π_t^*	-0.580208	0.241852**			-0.518549	0.245366**		
y_t^{gap}	0.650325	0.920841			0.600485	0.898789		
y_t^{gap*}	-2.640218	1.19603**			-2.654795	1.140082**		
q_t					-2.042386	1.717724		
i_t	-0.035561	0.053358			-0.032081	0.052283		
i_t^*	0.226074	0.039689***			0.230294	0.039769***		
σ (state 1)	0.147728	0.031519***			0.128585	0.031246***		
σ (state 2)	0.290339	0.049483***			0.303147	0.053504***		
Transition variable: interest rate paid on reserves								
$p(1, 1)$	0.927826	0.26806***			0.945049	0.268672***		
$p(1, 2)$	-1.305526	0.293768***			-1.31199	0.294249***		
Testing linearity against Markov-switching models								
	SupTS	10% cv	5% cv	1% cv	SupTS	10% cv	5% cv	1% cv
	20.094	3.344	4.429	6.266	33.405	3.425	4.304	6.883

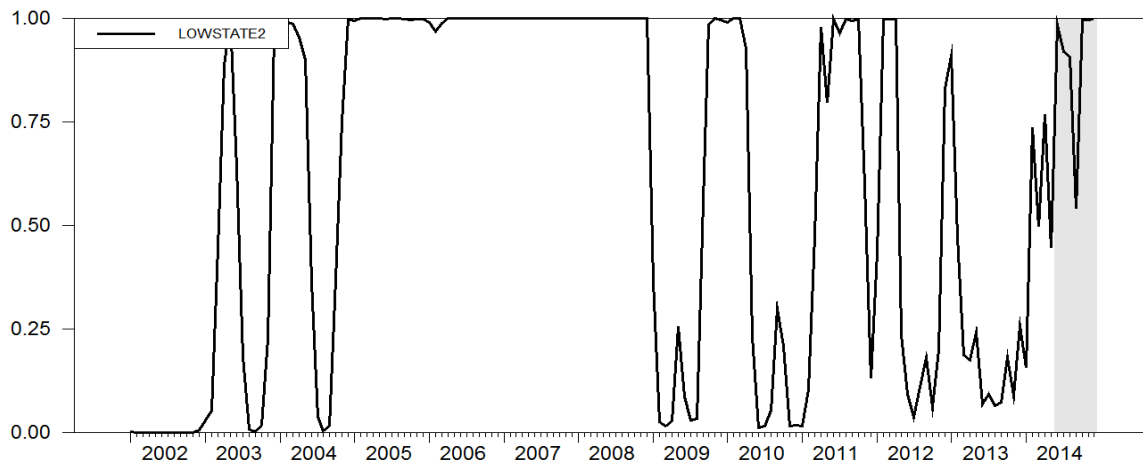
Table 1: Dependent variable: differences of USD vs. Eur exchange rate
Transition variable: the interest rate paid on reserves by the ECB
†: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively

Transition probabilities plotted in Figure 2 suggest that the USD vs. Eur exchange rate experienced several regime switching since the beginning of the crisis. The timing of these regime switching coincides with financial stresses experienced in the euro area (the bankruptcy of Lehman Brothers, Greek debt episodes, the sovereign debt crisis...).

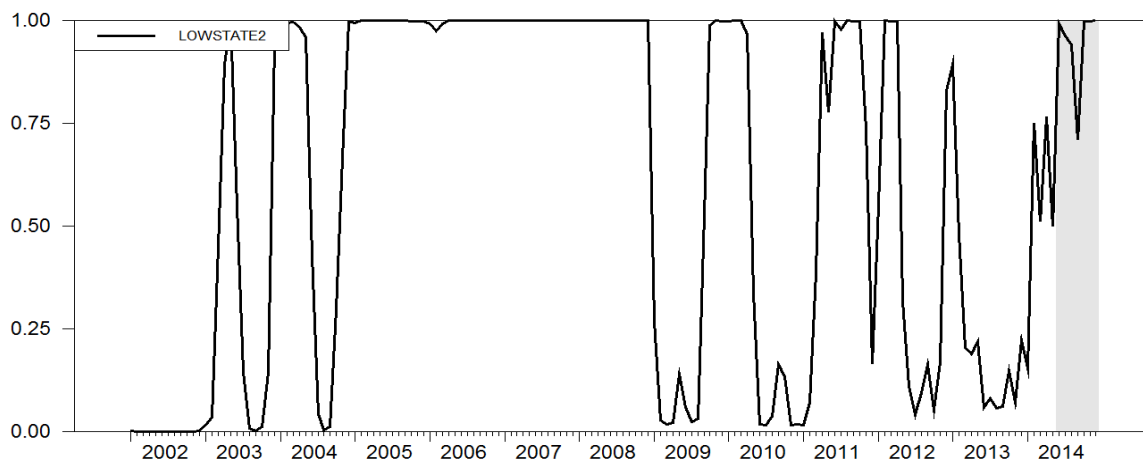
A mild depreciation pressure on the euro seemed to have started in February 2014. This is probably due to the decision of the FED of an additional (after the initial reduction in December 2013) reduction in the pace of purchases of longer-term Treasury securities and agency mortgage-backed securities.



(a) Dependent variable: differences of USD vs. Eur exchange rate



(b) Smoothed transition probability of being in the depreciation regime: without the real exchange rate



(c) Smoothed transition probability of being in the depreciation regime: with the real exchange rate

Figure 2: USD vs. Eur exchange rate

2.2 Foreign reserves minus gold

I consider here the euro area capital flows through changes in the euro area foreign reserves minus gold, an increase in capital inflows (outflows) increases (decreases) foreign reserves. Figure 3 shows a decrease in foreign reserves since the euro area went into negative territory.

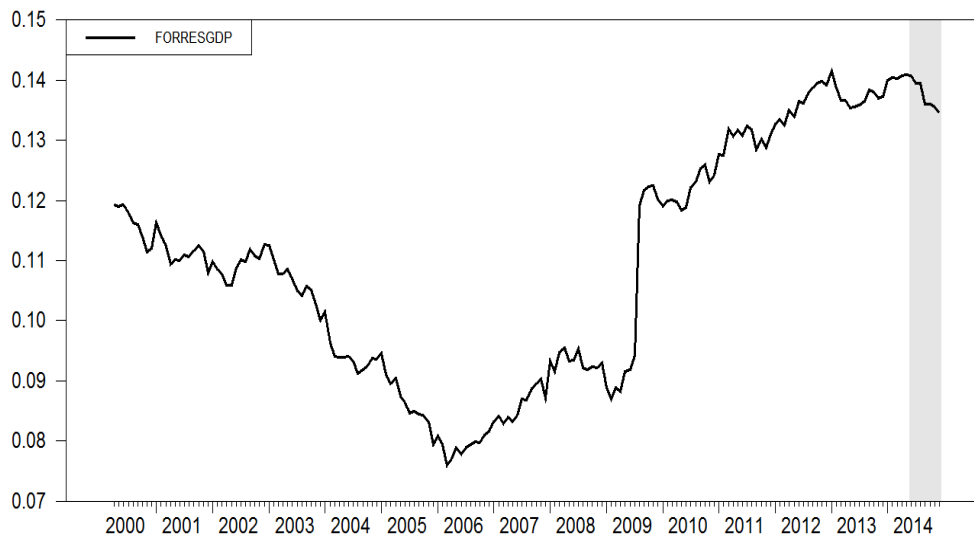
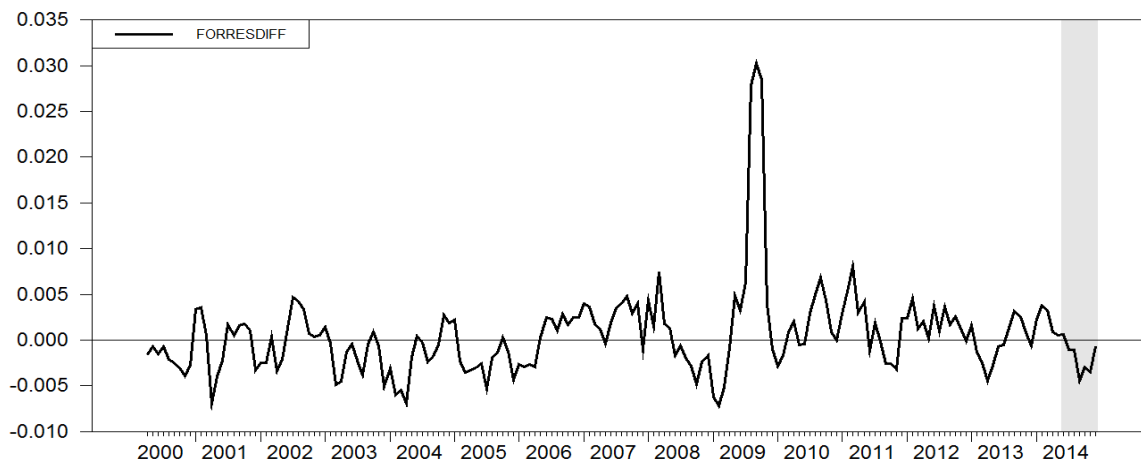


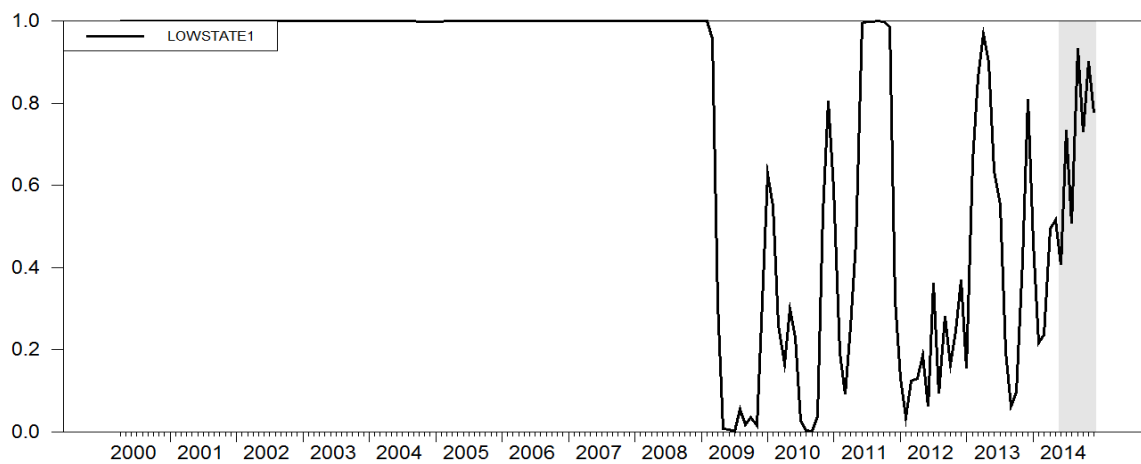
Figure 3: Euro area's foreign reserves minus gold scaled by GDP

MS-TVTP estimations presented in Table 2 suggest statistically significant regime switching. As was the case in the estimations of the exchange rate model, all significant coefficients have the expected sign, at the exception of the short term interest rate.

Switching probabilities plotted in Figure 4 follow approximately those of the exchange rate model and confirm the previous interpretation. Euro area capital flows (and by consequence the exchange rate) were significantly impacted by financial stresses experienced since the Lehman Brothers bankruptcy (Greek debt episodes, sovereign debt crisis...).



(a) Dependent variable: differences of foreign reserves scaled by GDP



(b) Smoothed transition probability of being in low foreign reserves regime

Figure 4: Euro area's foreign reserves minus gold

Variable	Estimation	Std-error†
Intercept (state 1)	-0.013593	0.008314
Intercept (state 2)	0.024881	0.006648***
y_t^{gap}	2.13226	0.460048***
y_t^{gap*}	-1.718673	0.537587***
$DJeuro_t$	-0.070602	0.138832
$SP500_t$	0.140659	0.151103
i_t	-0.002165	0.002634
i_t^*	0.004226	0.001763**
σ (state 1)	0.00058	0.000079***
σ (state 2)	0.000544	0.000163***
Transition variable: interest rate paid on reserves		
$p(1, 1)$	2.362166	0.623557***
$p(1, 2)$	-3.505629	1.559062**
Testing linearity against Markov-switching models		
	SupTS	10% cv 5% cv 1% cv
	41.241	3.511 4.338 6.347

Table 2: Dependent variable: differences of foreign reserves minus gold scaled by the GDP of the euro area

Transition variable: the interest rate paid on reserves by ECB

†: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively

3 The Danish experience

The goal of this paper is to assess the impact of going into negative territory, but isolating its effect in the euro area seems delicate. The specific financial and economic tensions that the euro area experienced since the Lehman Brothers' bankruptcy (Greek debt tensions episodes, sovereign debt crisis episodes, German constitutional court decision on ECB's programmes, euro area collective decision making...) and the several purchase programmes in both the US and the euro area complicate the analysis.

To better identify the impact of going into negative territory, I consider in this section the Danish experience. Denmark is a small economy, part of the European Union but not the euro area, with a credible fixed exchange rate regime and its decision to go into negative territory was merely a consequence of both its fixed exchange rate policy and the decision of the ECB to lower its policy rates

Furthermore, paying a negative interest rate on reserves did not push retail banking interest rates into negative territory (see Callesen (2013)). This suggests that banks' behavior should be considered closely which is possible thanks to disaggregated banking data published by Danmarks Nationalbank.

3.1 Monetary policy in Denmark

The primary objective of Denmark's monetary policy is to maintain price stability. To this end, Denmark has conducted a fixed exchange rate regime since the early 1980s (first against the D-Mark and from 1999 against the euro). This is done within the framework of the European Exchange Rate Mechanism, ERM II. The krone is kept stable within a narrow band, it may fluctuate by up to 2.25% on either side of its central rate, kr. 7.46038. As a result Danish monetary policy interest rates initially track euro area policy rates (see Spange and Toftdahl, 2014).

Danmarks Nationalbank conducts its monetary policy via its lending and deposit (current account and certificates of deposit) facilities which are available to banks and mortgage-credit institutes. Danmarks Nationalbank sets the discount rate (it does not refer to monetary policy facilities, but acts as a signal rate), the current account rate, the lending rate and the rate on certificates of deposit (see Danmarks Nationalbank, 2009).

Danmarks Nationalbank sets a limit for the monetary policy counterparties' total current account deposits. The monetary policy counterparties may exceed their individual limits (which is determined on the basis of their activities in the money market), provided that the overall limit is not exceeded. If the overall limit is exceeded, deposits exceeding the individual limits will be converted into certificates of deposit.

Before going into negative territory, Danmarks Nationalbank set the current account rate lower than the interest rate paid on certificates of deposit. Along with the limits on the current account deposits, this helped ensuring a well functioning money market and

prevented the build up of large current account deposits that may be used without notice to speculation if the krone is under pressure.

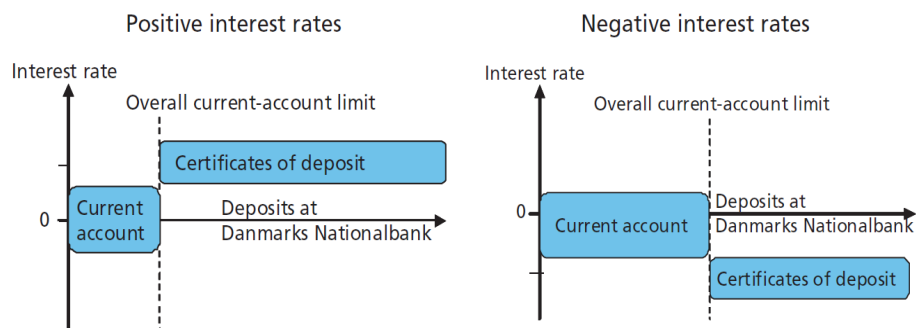


Figure 5: Deposit facilities before and after going into negative territory
Source: Jorgensen and Risbjerg (2012)

Due to its fixed exchange rate policy and in connection to the ECB reduction of policy rates, Danmarks Nationalbank went in July 2012 into negative territory. After going into negative territory, Danmarks Nationalbank set the interest paid on certificates of deposit lower than the current account rate⁹ and adjusted upwards the current account limits. Figure 5 shows the adjustments of interest rates and current account limits.

3.2 The exchange rate

Despite the high credibility of the fixed exchange rate regime in Denmark (which means that market participants take positions which in themselves stabilize the exchange rate of the krone), one can assess depreciation and appreciation pressures when considering movements around the central rate.

Figure 6 shows a depreciation of the exchange rate of the krone after going into negative territory and an appreciation when Denmark went back into positive territory. I estimate

⁹The interest rate paid on reserves used in the estimations below is defined as the lower bound of the corridor set by Danmarks Nationalbank, i.e. the rate on certificates of deposit when the Danmarks Nationalbank went into negative territory and the current account rate otherwise.

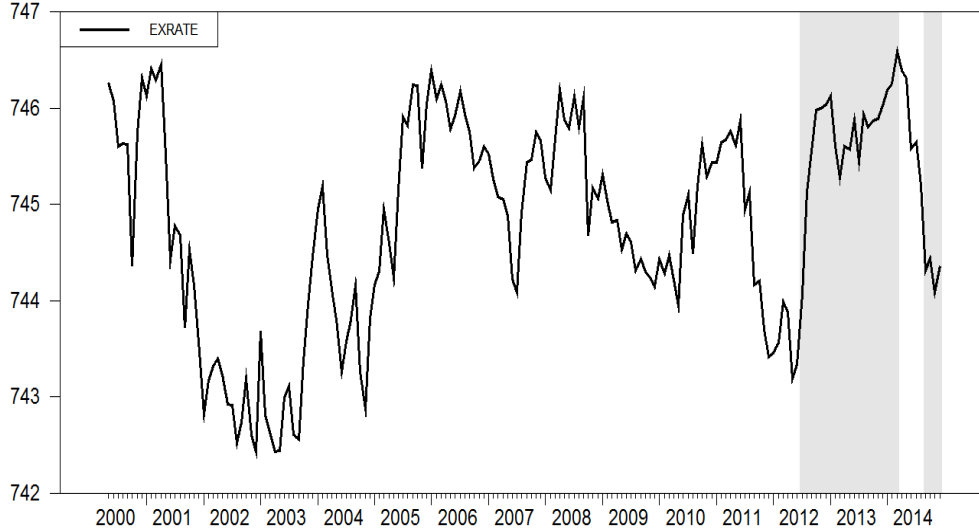


Figure 6: Danish krone vs. Eur exchange rate

here MS-TVTP of both the standard and smoothed specification of Taylor-rule fundamentals exchange rate models to assess these movements.

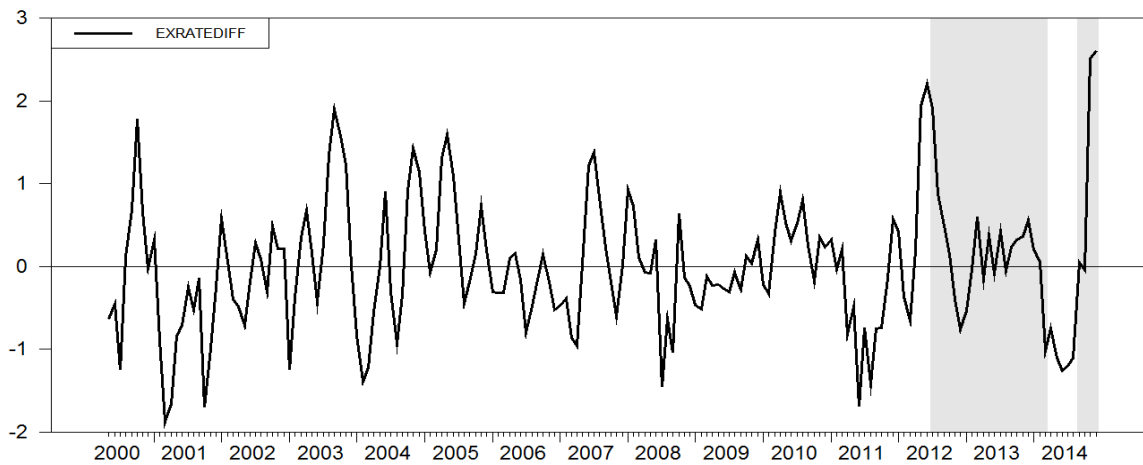
3.2.1 Standard specification

Results of the standard specification presented in Table 3 show statistically significant regime switching in the movements of the Danish krone vs. Eur exchange rate. At the exception of the output gap¹⁰, all significant coefficients have the expected sign. The central bank reacts to an increase in the inflation rate by increasing the interest rate which appreciates the currency, the central bank leans against the wind when the real exchange rate appreciates and an increase in the past short term interest rates appreciates the krone.

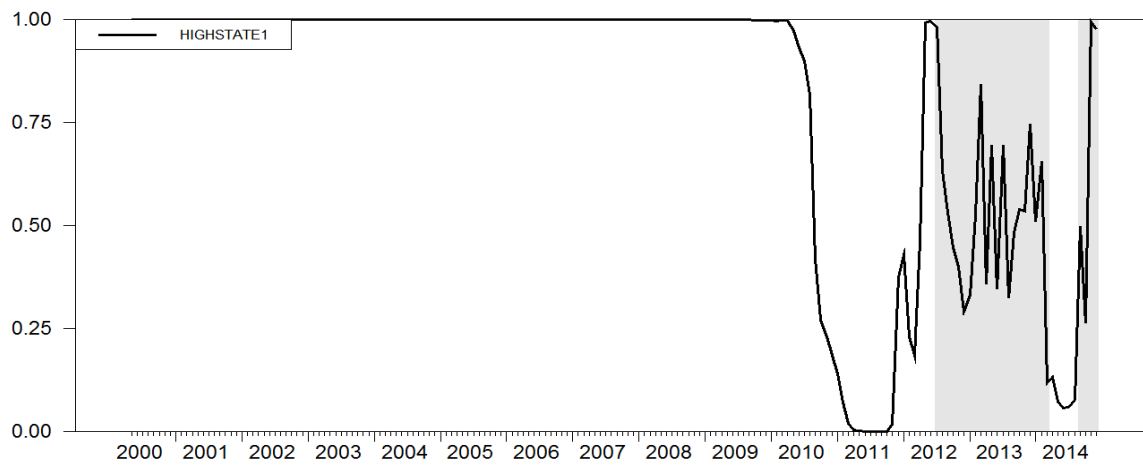
The transition probabilities plotted in Figure 7 show an appreciation pressure at the end of 2010 and until mid-2012 which is due to the perception by investors of the Danish krone as a safe haven.

After this episode, the *unilateral* decision of Danmarks Nationalbank to decrease policy rates by 25 basis points in May 2012 seems to have depreciated the krone. The exchange

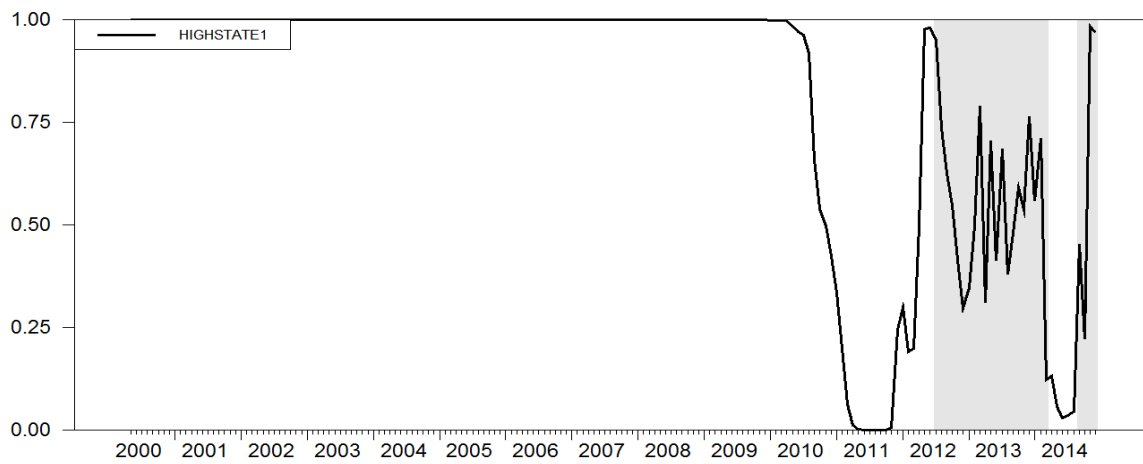
¹⁰This is a recurrent problem in the literature, see Chinn (2008) for more details.



(a) Dependent variable: differences of Danish krone vs. Eur exchange rate



(b) Smoothed transition probability of being in the depreciation regime: without the real exchange rate



(c) Smoothed transition probability of being in the depreciation regime: with the real exchange rate

Figure 7: Exchange rate - main specification

Variable	Without Real Exchange Rate				With Real Exchange Rate			
	Estimation	Std-error†			Estimation	Std-error†		
Intercept (state 1)	0.784419	0.26846***			0.715245	0.271041***		
Intercept (state 2)	-0.179465	0.205856			-0.294141	0.239571		
π_t	-0.309673	0.226248			-3.358696	1.379263**		
π_t^*	0.50573	0.540524			3.453618	1.418006**		
y_t^{gap}	2.050606	0.7765***			2.045165	0.779244***		
y_t^{gap*}	1.655859	2.108715			1.695429	2.121689		
q_t					-0.198263	0.088238**		
i_t	-0.169889	0.191233			-0.284185	0.198508		
i_t^*	-0.076472	0.216669			0.041071	0.225958		
σ (state 1)	0.518362	0.064209***			0.481765	0.060036***		
σ (state 2)	0.362555	0.10622***			0.424509	0.144495***		
Transition variable: interest rate paid on reserves								
$p(1, 1)$	2.293595	0.868354***			2.277595	0.813713***		
$p(1, 2)$	-3.400777	2.263511			-3.733302	3.075361		
Testing linearity against Markov-switching models								
	SupTS	10% cv	5% cv	1% cv	SupTS	10% cv	5% cv	1% cv
	32.685	3.358	4.399	6.210	37.652	3.305	4.022	5.505

Table 3: Dependent variable: differences of Danish krone vs. Eur exchange rate
Transition variable: the interest rate paid on reserves by Danmarks Nationalbank
†: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively

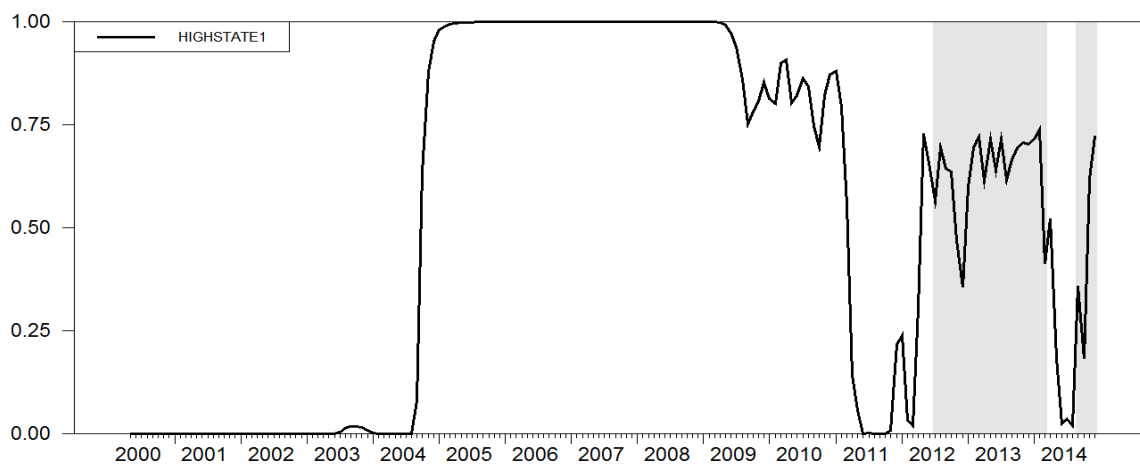
rate seems to have experienced a depreciation pressure during periods of negative territory (despite several increases in the current-account limits) and an appreciation pressure during periods of positive territory (see below for a more detailed analysis).

3.2.2 Smoothed specification

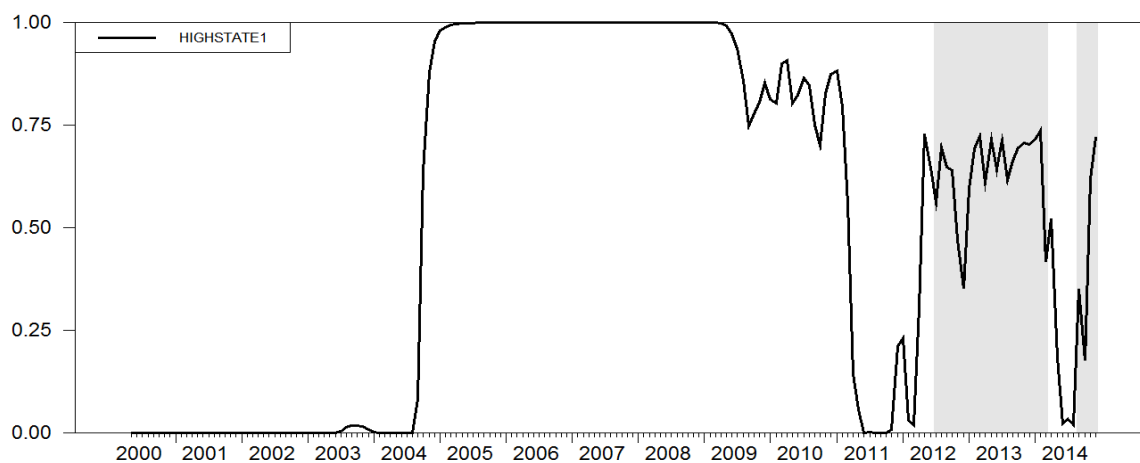
The specific framework of the fixed exchange rate in Denmark imply fluctuations of the exchange rate s_t around the central peg set by Danmarks Nationalbank. The Augmented Dickey-Fuller test, Table 4, show that both s_{t+3} and s_t are stationary at 10% which allows an alternative smoothed specification of the Taylor-rule fundamentals exchange rate model.

Augmented Dickey-Fuller test		
Variable	stat	p-value
s_{t+3}	-1.9682	0.0472
s_t	-1.7573	0.0749

Table 4: Augmented Dickey-Fuller test



(a) Smoothed transition probability of being in the depreciation regime: without the real exchange rate



(b) Smoothed transition probability of being in the depreciation regime: with the real exchange rate

Figure 8: Exchange rate - smoothed specification

Variable	Without Real Exchange Rate				With Real Exchange Rate			
	Estimation	Std-error†			Estimation	Std-error†		
Intercept (state 1)	0.126245	0.185314			0.123871	0.186628		
Intercept (state 2)	-0.578099	0.206422***			-0.581217	0.207407***		
$s_t - \text{central rate}$	0.553187	0.057544***			0.556388	0.060249***		
π_t	-0.300095	0.187325			-0.54509	1.323662		
π_t^*	0.144961	0.442629			0.397313	1.418334		
y_t^{gap}	2.077814	0.581391***			2.091036	0.584992***		
y_t^{gap*}	2.415839	1.539417			2.365089	1.564784		
q_t					-0.015537	0.083104		
i_t	-0.092968	0.151626			-0.101996	0.159484		
i_t^*	-0.023958	0.172145			-0.015289	0.178908		
σ (state 1)	0.221445	0.037753***			0.220113	0.0382***		
σ (state 2)	0.616664	0.107942***			0.619413	0.109555***		
Transition variable: interest rate paid on reserves								
$p(1, 1)$	1.436901	0.960482			1.437717	0.977482		
$p(1, 2)$	-0.967367	0.254724***			-0.96742	0.255398***		
Testing linearity against Markov-switching models								
	SupTS	10% cv	5% cv	1% cv	SupTS	10% cv	5% cv	1% cv
	39.889	3.410	4.073	5.489	41.241	3.511	4.338	6.347

Table 5: Dependent variable: s_{t+3} - the central peg rate
Transition variable: the interest rate paid on reserves by Danmarks Nationalbank
†: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively

As was the case of the standard specification, results of the smoothed specification presented in Table 5 show statistically significant regime switching. And, transition probabilities of the smoothed specification, plotted in Figure 8, confirm the conclusions and seem more stable than the standard specification¹¹.

3.3 Banking flows

Results presented above suggest that going into negative territory did put a depreciation pressure on the Danish krone. As noted previously, retail banking interest rates stayed in positive territory even when banks (and mortgage credit institutes) payed a negative interest rate on reserves. This suggests that banks' behavior should be closely assessed.

I consider in this section Danish banks' balance sheet composition, banks' external (rest of the world) vs. internal net assets and banks' net assets held in foreign currencies vs.

¹¹Introducing higher granularity of the regimes might be more suitable with the data. Hierarchical Hidden Markov Structure can be considered, see Fine et al. (1998) and Charlot and Marimoutou (2011). But this is left for future work.

Danish krone¹². Results presented in Table 6 show that the composition of banks' balance sheet experienced statistically significant regime switching.

Variable	External vs. internal assets				Assets by currency			
	Estimation	Std-error [†]			Estimation	Std-error [†]		
Intercept (state 1)	0.040844	0.01011***			0.045724	0.011129***		
Intercept (state 2)	0.057547	0.015948***			0.018321	0.008208**		
y_t^{gap}	0.097304	0.256582			-0.057071	0.102827		
y_t^{gap*}	2.614083	0.613099***			0.748492	0.282503***		
$OMXC_t$	-0.025906	0.032219			-0.006508	0.033824		
$DJeuro_t$	0.037591	0.031398			-0.003631	0.032138		
i_t	0.015280	0.008307*			0.007459	0.006932		
i_t^*	-0.031043	0.01043***			-0.019327	0.007938**		
σ (state 1)	0.000215	0.000053***			0.000514	0.000065***		
σ (state 2)	0.000507	0.000068***			0.000253	0.000081***		
Transition variable: interest rate paid on reserves								
$p(1,1)$	9.356073	10.314041			2.392929	0.949438**		
$p(1,2)$	-1.138888	0.354346***			-3.317421	1.828852*		
Testing linearity against Markov-switching models								
	SupTS	10% cv	5% cv	1% cv	SupTS	10% cv	5% cv	1% cv
	25.885	3.036	4.147	5.704	11.544	3.272	4.158	6.004

Table 6: Dependent variables: banks' assets by country and currency
[†]: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively

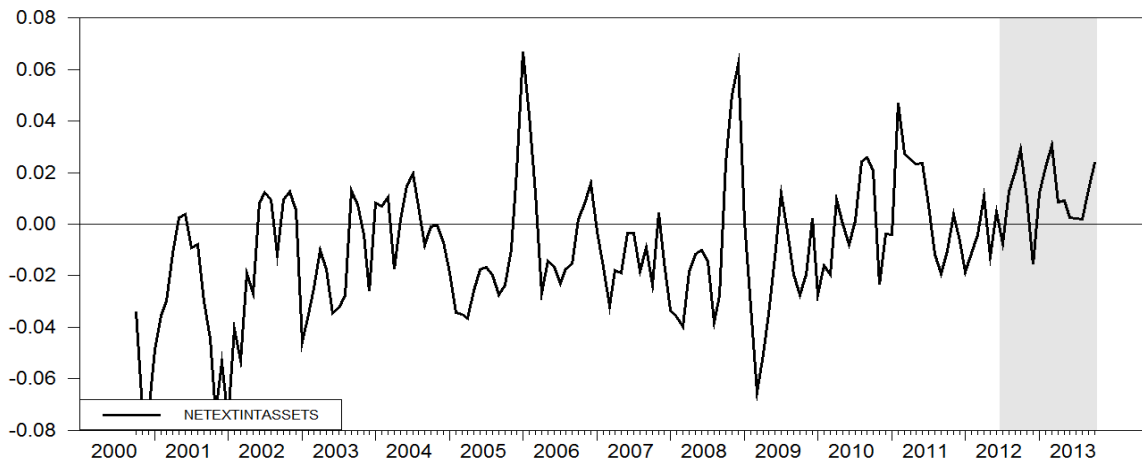
Signs of all significant coefficients are as expected at the exception of both home and foreign (euro area) policy rates. The fixed exchange rate in Denmark implies that Danish policy rates track the policy rates in the euro area which explains these results.

Figures 9 and 10 plot dependent variables and transition probabilities of both estimations. They both show a reversal in banking flows after going into negative territory.

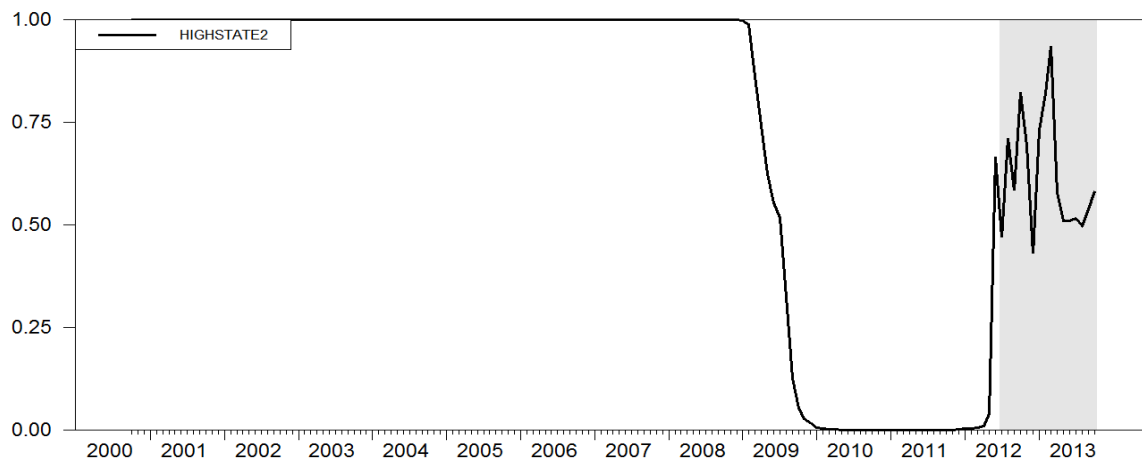
On the one hand, after the decision of Danmarks Nationalbank to lower the interest rate it pays into negative territory, banks (the impacted counterpart) seems to have reacted by increasing its net assets in foreign economies and net assets held foreign currencies.

On the other hand, in contrast to banks' external vs. internal net assets, banks' net assets by currency reacted sharply two months before Danmarks Nationalbank decision to

¹²Data on Monetary and Financial Institutions published by Danmarks Nationalbank experienced a structural break in October 2013. To avoid any bias due to this structural break, I chose to not include data after this date.

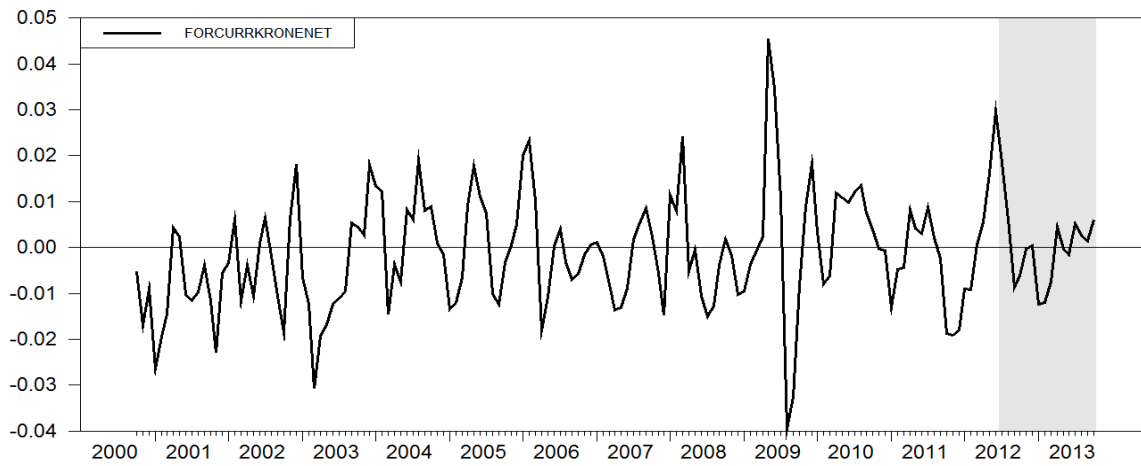


(a) Dependent variable: differences of external vs. internal net assets scaled by Banks' total assets

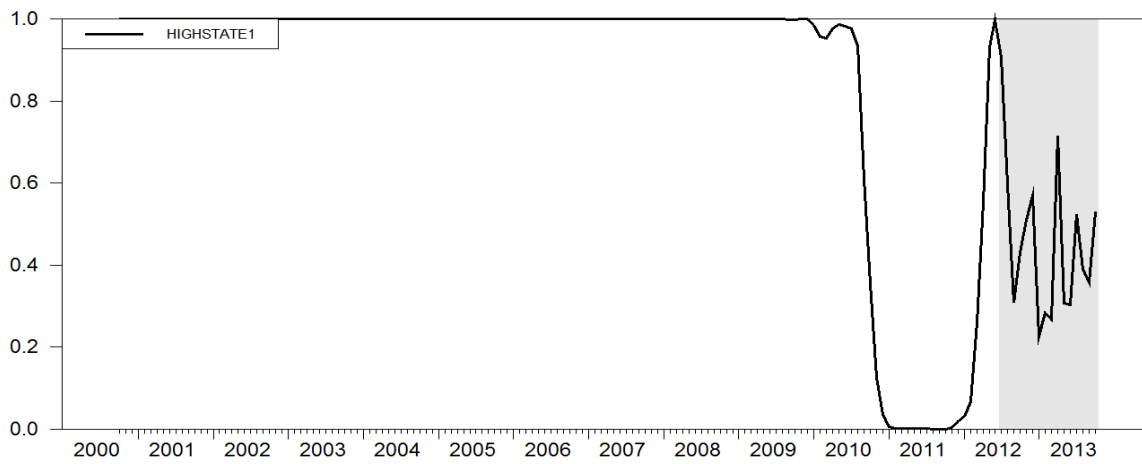


(b) Smoothed transition probability of being in high external vs. internal net assets

Figure 9: Banks external vs. internal net assets



(a) Dependent variable: differences of foreign vs. krone net assets scaled by Banks' total assets



(b) Smoothed transition probability of being in high foreign vs. krone net assets

Figure 10: Banks net assets by currency

go into negative territory. This is probably the consequence of the *unilateral* decision of Danmarks Nationalbank to lower its policy rates by 25 basis points.

4 Policy differentials or negative territory?

Setting negative nominal interest rates is one of the unconventional policy implemented after the Great Recession to overcome the ZLB. But its impact is yet to be completely determined. Is it the same to lower interest rates in positive or negative territory? Is there a distinct impact of going into negative territory?

McAndrews (2015) argues that negative nominal rates are qualitatively different from positive rates. In this section, I consider periods of negative territory in both the euro area and Denmark and show that going into negative territory seem to have a distinct impact from lowering interest rates.

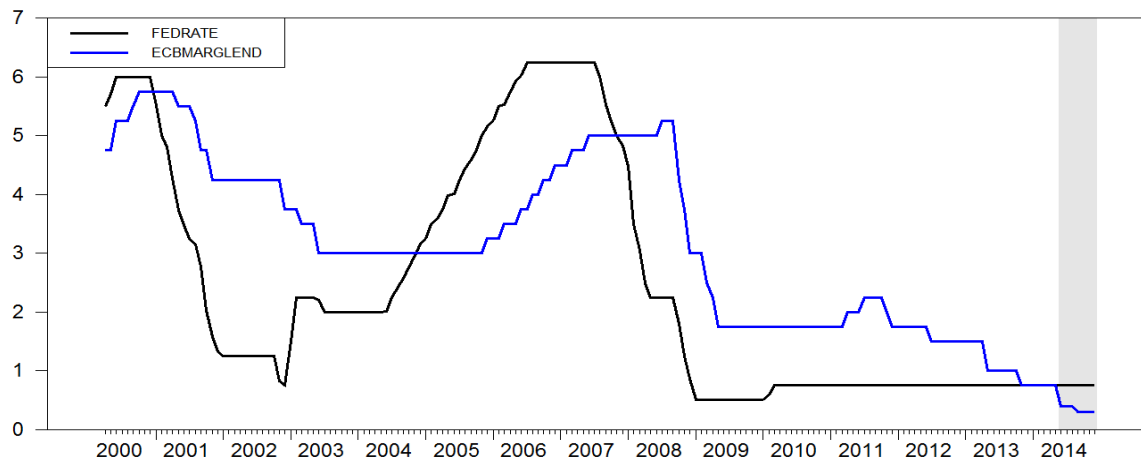
I consider policy differentials between both the higher and lower bound of the corridor. But I focus on the lower bound since it became the main policy rate of central banks after the Great Recession.

4.1 ECB vs. the FED

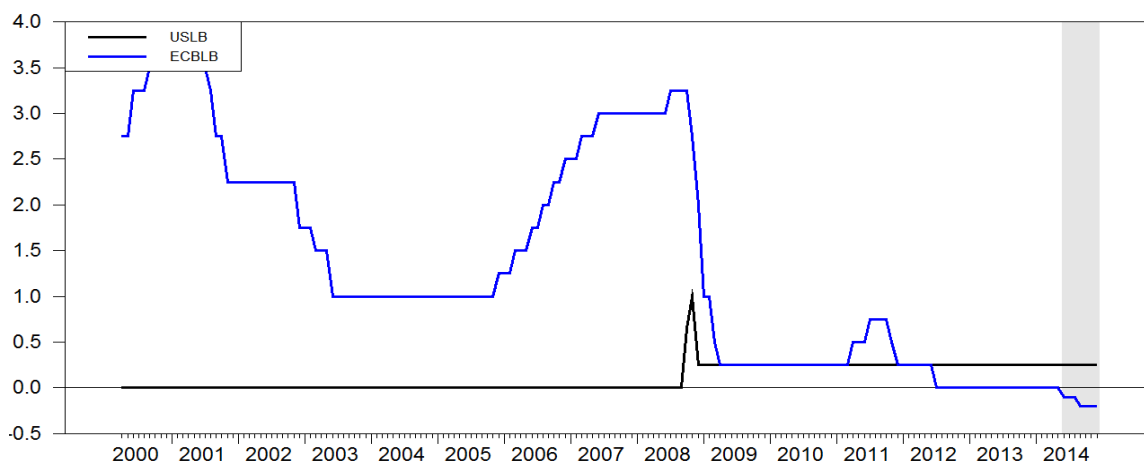
Both the higher and the lower bounds of the corridor in the US and the euro area, plotted in Figure 11, imply policy differentials that lead to capital outflows of the euro area during the period of negative territory.

This is confirmed by the transition probabilities of exchange rate models and foreign reserves, plotted in Figures 2 and 4. They show that during the period of negative territory the euro experienced a depreciation pressure and significant net capital outflows.

Is this depreciation pressure due only to policy differentials? The different economic and financial stresses specific to the euro area, the QE in the US and the euro area purchase



(a) The higher bound of the corridor in the euro area and the US



(b) The lower bound of the corridor in the euro area and the US

Figure 11: Policy rates in the euro area and the US

programmes complicate the analysis. For instance, during the highest tension due to the sovereign debt crisis in 2011 and despite an increase of the interest rate by the ECB, the euro experienced a depreciation pressure and capital outflows.

The Danish experience, analyzed below, present several episodes which disentangle the impact of going into negative territory from the effect of policy differentials.

4.2 Danmarks Nationalbank vs. ECB

Denmark has conducted a fixed exchange rate regime since the early 1980s (first against the D-Mark and from 1999 against the euro). As a result of the fixed exchange rate policy, Danish monetary policy initially tracks the monetary rates of the ECB which simplifies assessing the impact of going into negative territory.

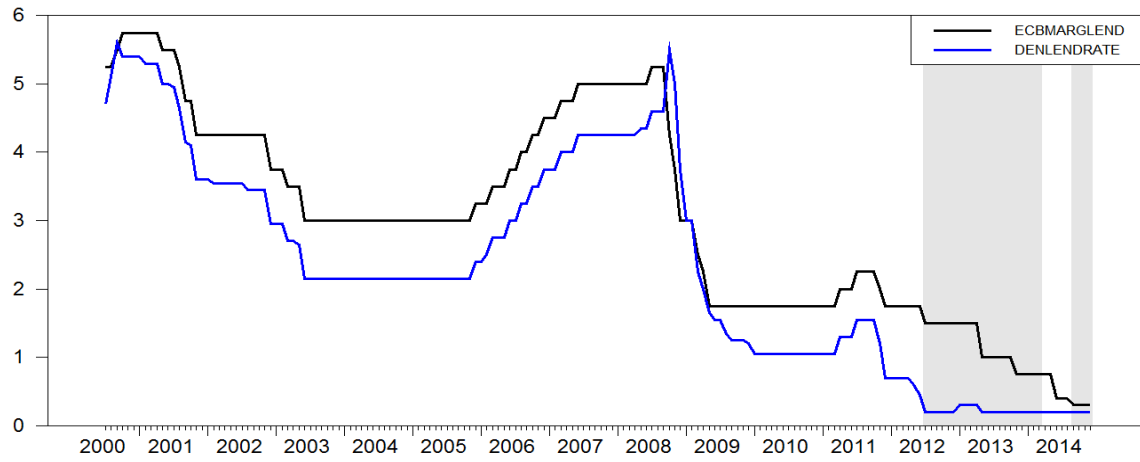
Danmarks Nationalbank raised the current-account limits simultaneously when it went into negative territory. This measure weakens the impact of policy differential that pushes towards net capital outflows from Denmark. Despite this increase in the current-account limits, one can note, as argued by McAndrews (2015), several episodes which suggest a distinct impact of going into negative territory from lowering interest rates.

Both exchange rate models and banks' net assets in foreign currencies vs. Danish krone, unlike banks' external vs. internal net assets, seem to react two months before going into negative territory. This can be explained by the decision of Danmarks Nationalbank to lower *unilaterally* its policy rates two months before going into negative territory.

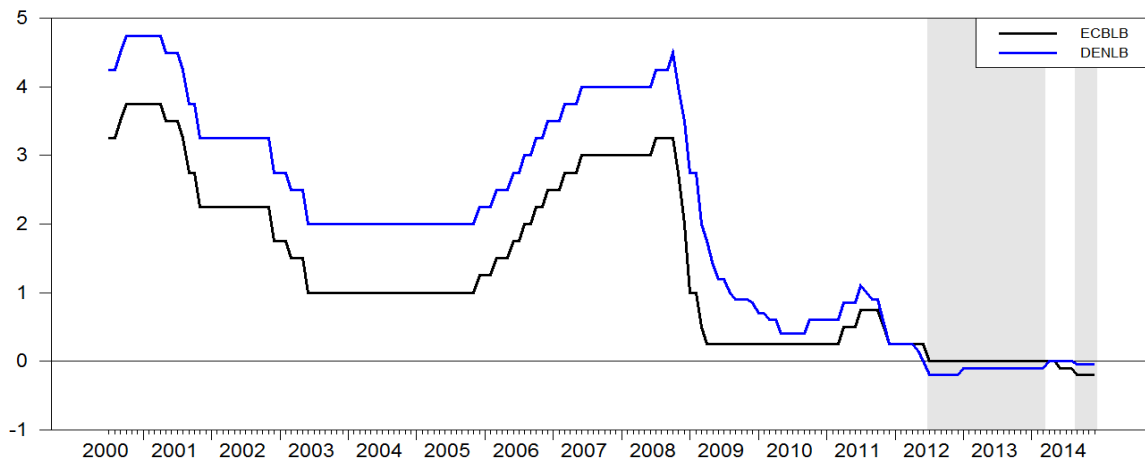
Several increases (the end of 2012, mid-2013) during periods of negative territory of policy differentials in the higher bound of the corridor (in favor Danish capital and banking inflows) can not be observed during periods of negative territory.

When considering the lower bound of the corridor, one can note, at the beginning of 2013, an increase of policy differentials in favor of capital and banking inflows to Denmark but this can not be observed. Instead, transition probabilities of both the exchange rate and banking flows variables were stable in the depreciation regime and the high banking outflows regime.

Furthermore, during the positive territory period in 2014, only the ECB lowered its policy rates. This should appreciate the Danish krone but this can not be observed either. Finally, when Danmarks Nationalbank went back into negative territory in June 2014, policy differentials between the euro area and Denmark increased again in favor of Danish krone



(a) The higher bound of the corridor in the euro area and Denmark



(b) The lower bound of the corridor in the euro area and Denmark

Figure 12: Policy rates in the euro area and Denmark

appreciation. But, not only such appreciation can not be observed, but one can note a depreciation of the Danish krone during this period.

Conclusion

Negative policy rates were one of the unconventional policies implemented after the Great Recession to overcome the Zero Lower Bound. The impact of this measure is yet to be clearly determined. Does lowering interest rates has the same effect in positive and negative territory? Is there a distinct impact of going into negative territory?

I assess in this paper the impact of paying a negative interest rate on reserves. I consider its impact on the exchange rate and capital and banking flows by using data from the euro area and the Danish experience.

I find, as argued by McAndrews (2015), that going into negative territory has a distinct impact from lowering interest rates. It put a depreciation pressure on the exchange rate through a reversal in banking flows.

Both McCallum (2000) and Svensson (2000b) showed that policies based on a depreciation of the exchange rate can be implemented to allow the economy to escape from a liquidity trap. The results presented above are to be confirmed with future research on the Swedish and the Swiss experiences, but they suggest that paying a negative interest rate on reserves can be an efficient measure to depreciate the currency which might allow the economy to escape a liquidity trap.

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