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Swedish krona-euro return volatility and non-traditional monetary policies

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Abstract

Using the EGARCH and MGARCH approaches, this study explores the effects non-traditional monetary policies and regional currency exchange returns have on Swedish krona-euro exchange rate return volatility. Using data from 4 January 1999 through 30 September 2018, the study finds the mean equations exhibit market efficiencies while the variance equations exhibit significant GARCH effects, small asymmetric effects, and volatility clustering. The study concludes that the non-traditional monetary policies adopted by the Sveriges Riksbank successfully reduced Swedish krona-euro return volatility. The quantitative easing monetary policy reduced the influence and persistence the term structure interest rate differential had on Swedish krona-euro return volatility. The study also finds the negative nominal interest rate monetary policy reduced the influence and persistence the short-term interest rate differential had on Swedish krona-euro return volatility. The Swedish krona-Danish krone returns, and Swedish krona-Norwegian krone returns exhibited large conditional correlations or spillover effects that increased Swedish krona-euro return volatility.

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1. Introduction

Sweden is the 31st largest export economy in the world and 10th largest export economy in Europe. Over 74% of Sweden's exports are with other European countries and nearly 53% of its exports are with countries that use the euro, Danish krone, or Norwegian krone as currency. Despite signing the Treaty of Accession in 1994 and joining the European Union (EU), Sweden has not joined the eurozone or the Exchange Rate Mechanism II (ERM II). By maintaining the Swedish krona as its currency, Sweden's central bank, Sveriges Riksbank, independently sets its monetary policy to achieve an inflation target of two percent. This independence proved useful when market pressures arising from the global financial crisis caused the Riksbank to frequently miss its inflation target. In response to the global financial crisis and lack of conventional monetary policy effectiveness, the Riksbank used non-traditional monetary policy tools to restore financial market stability, avoid deflation, and encourage economic growth. The timing and magnitude of the non-traditional monetary policy changes were different from those adopted by the European Central Bank (ECB), Denmark Nationalbank, and Norges Bank.

A goal of the non-traditional monetary policies adopted during and following the global financial crises was to increase liquidity in the financial system. The non-traditional monetary policies included offering financial institutions loans with extended maturities and government-backed credit lines, quantitative easing (QE), and lowering interest rates. QE, also known as large-scale asset purchases, is when a central bank buys government bonds or other financial assets in order to increase liquidity and lower interest rates. In theory, the higher levels of liquidity and lower interest rates would encourage banks to loan funds thereby increasing investment and consumer spending. Table I provides highlights of Sweden, eurozone, Denmark, and Norway financial events and policy changes from 1999 through 2018.

Prior to the recent financial crisis, economists and central bank officials assumed that a zero nominal interest rate policy represented the lower bound of a nominal interest rate target. If a zero nominal interest rate policy was implemented, conventional wisdom was that it would lead to a liquidity trap. Any additional money supply increases would have no expansionary effect on aggregate demand since households and businesses would have met their liquidity needs. As the negative economic impacts of the financial crisis persisted and the minimal effectiveness of fiscal policies became apparent, several central banks discussed the possibility of implementing a negative nominal interest rate (NNIR) target despite liquidity trap concerns. The use of a NNIR policy was first introduced by Denmark Nationalbank in July 2012 to discourage appreciation of its currency and to defend its ERM II peg with the euro. In June 2014, the NNIR policy was introduced by the European Central Bank (ECB); this action was quickly followed by the Swiss National Bank in January 2015 and the Riksbank in February 2015. The Norges Bank adopted a negative reserve rate in September 2015. By 2016, the central banks in Bulgaria, Denmark, the e eurozone, Hungary, Japan, Norway, Sweden, and Switzerland had implemented NNIR policies.

The implementation of non-traditional monetary policies has led to a new body of literature. One area of research has focused on a theoretical re-evaluation of the nominal interest rate lower bound assumption. Buiter (2009) offered three methods to eliminate the zero nominal interest rate lower bound and thereby allowing central banks greater flexibility during periods of non-traditional monetary policies. The methods eliminated the asymmetry that arises with a zero

Table I: Sweden, Eurozone, Denmark, and Norway financial event highlights 1999 - 2018

Year	Events
1999	Euro introduced and eleven of the 15 EU members fix their national currency value to the euro. The United Kingdom and Denmark opted not to fix their national currency values to the euro. Sweden and Greece did not meet the eurozone criteria to join the eurozone. Norway is a member of the European Economic Area and not a member of the EU.
2001	Greece joined the eurozone.
2002	Euro notes and coins are introduced and the twelve eurozone countries phase-out the use of their national currencies.
2004	Ten countries join the EU, expanding EU membership to 25 countries.
2007	Slovenia joined the eurozone.
	The financial crisis began with the bankruptcy of several U.S. subprime mortgage lenders during the first half of 2007. The financial crisis spread worldwide during the second half of 2007.
	During August, the ECB supplied more liquidity to the interbank market through loans.
2008	Malta and Cyprus joined the eurozone
	On September 15th, Lehman Brothers filed for Chapter 11 bankruptcy. It was the largest bankruptcy filing in U.S. history leading to financial institution liquidity problems around the world and an international banking crisis.
	The Riksbank offered loans with extended maturities denominated in U.S. dollars and Swedish krona to Swedish banks to increase financial system liquidity.
2009	During January, Iceland's banking system collapsed. Budget deficit and debt concerns emerged for several EU countries including Cyprus, France, Greece, Ireland, Portugal, and Spain.
	Denmark, Estonia, Latvia, and Lithuania join the ERM II. The ERM II, which is voluntary but a criterion for joining the eurozone, is a fixed exchange rate system that allows the exchange rate with the euro to fluctuate within a ±2.25% band.
	During May, the ECB began purchasing public sector, corporate, and asset-backed securities to maintain liquidity in financial markets. By July, the Riksbank, Denmark Nationalbank, and Norges Bank took similar actions to increase financial system liquidity.
2010	Debt concerns grew for Greece, Ireland, Portugal, and Spain. There was speculation that Greece may leave the eurozone. The EU and the International Monetary Fund (IMF) work together to restructure debt for several EU countries.
2011	Estonia joined the eurozone.
	The debt crisis continued within the eurozone with bailouts, emergency loans, and/or austerity measures approved for Cyprus, Greece, Ireland, Italy, Portugal, and Spain.* During February, the eurozone finance ministers established the European Stability Mechanism as a permanent bailout fund. During October, G20 finance ministers met in Paris and discussed solutions to the eurozone debt crisis.
2012	During July, the Denmark Nationalbank implemented a negative interest rate policy to discourage appreciation of its currency and to defend its ERM II peg with the euro.
2013	On December 28, the Riksbank lowered its overnight deposit rate to 0%.
2014	During June, the ECB implemented a negative interest rate policy.
	On July 9, the Riksbank lowered its overnight deposit rate, the interest rate banks receive on overnight deposits, below 0%. On October 29, the Riksbank lowered its repo rate, the interest rate banks pay when they borrow overnight from the Riksbank, to 0%.
2015	On February 2, the Riksbank lowered its repo rate below 0%.
	On January 22, the ECB announced it was expanding its asset purchases program, which peaked during 2016 through the first quarter of 2017.
	During February, the Sveriges Riksbank expanded its QE program to avoid deflation.
	On June 18th, the Norges Bank lowered its reserve rate to 0% and on September 25th, lowered it below 0%. The Norges Bank other policy rates remained above 0%.
2016	On June 23, the United Kingdom voted to leave the EU.

* The year the EU countries exited the bailout program: 2013, Ireland; 2014, Portugal and Spain; 2016, Cyprus; 2018, Greece. Italy was not offered a bailout plan but instead approved an austerity package during December 2011.

nominal interest rate lower bound and no nominal interest rate upper bound. Paying negative interest on currency or taxing currency, is a method often mentioned in other papers. Wen and Dong (2017) found a NNIR policy is possible if holding money is costly. Their model also concluded that a NNIR policy can be effective and that the zero nominal interest rate lower bound is an unnecessary constraint on monetary policy actions. Empirical assessments of QE and NNIR policies have focused on the impacts of monetary policy transmission on deposit rates and bank profits. Bech and Malkhozov (2016) examined the effects of NNIR policies implemented by the Denmark Nationalbank, the European Central Bank, the Riksbank, and the Bank of Japan. They found that negative and positive nominal interest rate policies similarly transmit through to money market rates, but that mortgage rates by policy design were insulated against the NNIR policy. Kerbl and Sigmund (2016) found that in a low interest rate environment, NNIR policies can reduce profitability creating increased risks, especially for small deposit banks. Similarly, Arteta et al (2018) found that NNIR policies could pose risks to financial stability and have a significant impact on bank profitability. Lopez et al (2018) results however found benign implications of NNIR policy for commercial banks.

This study adds to the empirical literature by exploring non-traditional monetary policy effects on Swedish krona-euro exchange rate return (SKE) volatility. Similar to other financial asset volatility research, exchange rate volatility research has found that the variance of the current error term reflects conditional heteroskedasticity and volatility clustering. This means that the variance is non-constant, and that periods of low volatility follow periods of low volatility, and periods of high volatility follow periods of high volatility (see select articles Meese and Rogoff 1983, Erdemlioglu et al. 2012, and Omari et al. 2017). Since the ordinary least squares process assumes homoskedasticity of the error term, the generalized autoregressive conditional heteroskedasticity (GARCH) approach, which allows for volatility changes during different time periods, is frequently used when examining financial data. The GARCH approach and its extensions use a multi-step process that predicts the variation of each error term and explores the causes of the volatility. The GARCH approach and its extensions also investigate the persistence of shocks over time.

In this study, the two questions examined are: Do non-traditional monetary policies influence SKE volatility? Is there interdependence of volatility across exchange rate markets that influence SKE volatility during non-traditional monetary policy periods? The two GARCH extensions used to answer these questions are the exponential generalized autoregressive conditional heteroskedastic (EGARCH) and dynamic conditional correlation multivariate generalized autoregressive conditional heteroskedastic (DCC MGARCH). The EGARCH approach investigates volatility by accounting for volatility clustering and allowing the variance associated with negative shocks and positive shocks to be different. If SKE volatility responds differently to negative shocks and positive shocks, accounting for the magnitude as well as the positivity or negativity of the variance is important when answering the first question. The DCC MGARCH approach investigates the potential interdependence of volatility across exchange rate markets while allowing for conditional correlations to vary over time. The DCC MGARCH approach provides insights into how information is transmitted and disseminated across the Swedish krona-euro, Swedish krona-Norwegian krone and the Swedish krona-Danish krone markets by examining volatility and the correlation of volatility across these exchange rate markets. Accounting for the correlation of volatility is necessary to answer the second question.

2. Methodology

Empirical literature has found that daily returns of financial assets such as stocks, bonds and exchange rates are not normally distributed but are heavy-tailed and skewed distributions. In addition, exchange rate returns and stock price returns exhibit heteroskedasticity and volatility clustering (see select articles Black 1976, Merton 1980, Nelson 1991, and Bekaert, 2000). As an extension of the autoregressive conditional heteroskedastic (ARCH) model developed by Engle (1982), Bollerslev (1986) developed a GARCH approach for data that accounts for volatility clustering and non-normal error distributions by simultaneously estimating a mean equation and a variance equation. The variance equation accounts for the internal shocks of the previous day's residual variance and the previous day's squared residual and may include additional independent variables to account for significant exogenous shocks. This study uses two GARCH extensions to examine SKE volatility, the EGARCH approach and the DDC MGARCH approach.

The EGARCH approach includes an asymmetric response parameter that allows for different exchange rate volatility responses depending on whether the there is a negative or positive shock. The general form of the EGARCH approach as proposed by Nelson (1991) is

$$R_t = \mu + \rho X_t + \epsilon_t \text{ where } \epsilon_t = Z_t\sqrt{\sigma_t^2} \quad (1)$$

and

$$\ln(\sigma_t^2) = \omega + \alpha(|Z_{t-1}| - E|Z_{t-1}|) + \Upsilon Z_{t-1} + \beta\ln(\sigma_{t-1}^2) \quad (2)$$

where equation (1) is the mean equation and equation (2) is the conditional variance equation. R is the daily percentage return for the Swedish krona-euro exchange rate; X are the independent variables and may include lag terms; σ_t^2 is the conditional volatility; ω is the GARCH constant; α is the GARCH error coefficient and represents the symmetric effect of the equation. ϒ is the weighted long-run variance and captures possible asymmetric shock responses. If $\Upsilon = 0$, then the variance is symmetric. When $\Upsilon > 0$, it suggests that positive news is more destabilizing than negative news. If $\Upsilon < 0$, then positive shocks generate less volatility than negative shocks. β is the GARCH lag coefficient which measures the persistence in conditional volatility and measures how quickly the variance reverts towards the long-run average. When β is relatively large, then volatility takes a long time to die out following a crisis in the market. Unlike the GARCH approach, the EGARCH approach places no restrictions on the estimated parameters to ensure non-negativity of the conditional variance (Francq et al. 2013). Since the $\ln(\sigma_{t-1}^2)$ captures conditional volatility, even if the parameters are negative, the $\ln(\sigma_{t-1}^2)$ will be positive. This is an advantage of the EGARCH approach.

The DCC MGARCH approach investigates the potential interdependence of volatility across exchange rate markets by allowing for the conditional covariances of the errors to follow an autoregressive moving average structure. The DCC MGARCH captures the dynamics of conditional correlations and identifies the potential interdependence or spillover effects of exogenous events on the variance equation. As proposed by Engle (2002), the DCC MGARCH approach is

$$R_t = \mu + \rho X_t + \epsilon_t \text{ where } \epsilon_t = Z_t\sqrt{H_t^2} \quad (3)$$

$$H_t = D_t^{0.5} C_t D_t^{0.5} \text{ and } h_{ij,t} = s_{ij} + \alpha_{ij}\epsilon_{i,t-1}\epsilon_{j,t-1} + \beta_{ij}h_{ij,t-1} \quad (4)$$

$$C_t = diag(Q_t)^{-0.5} Q_t diag(Q_t)^{-0.5} \quad (5)$$

$$Q_t = (1 - \lambda_1 - \lambda_2)C + \lambda_1 \tilde{\epsilon}_{t-1}\tilde{\tilde{\varepsilon}}_{t-1} + \lambda_2 Q_{t-1} \quad (6)$$

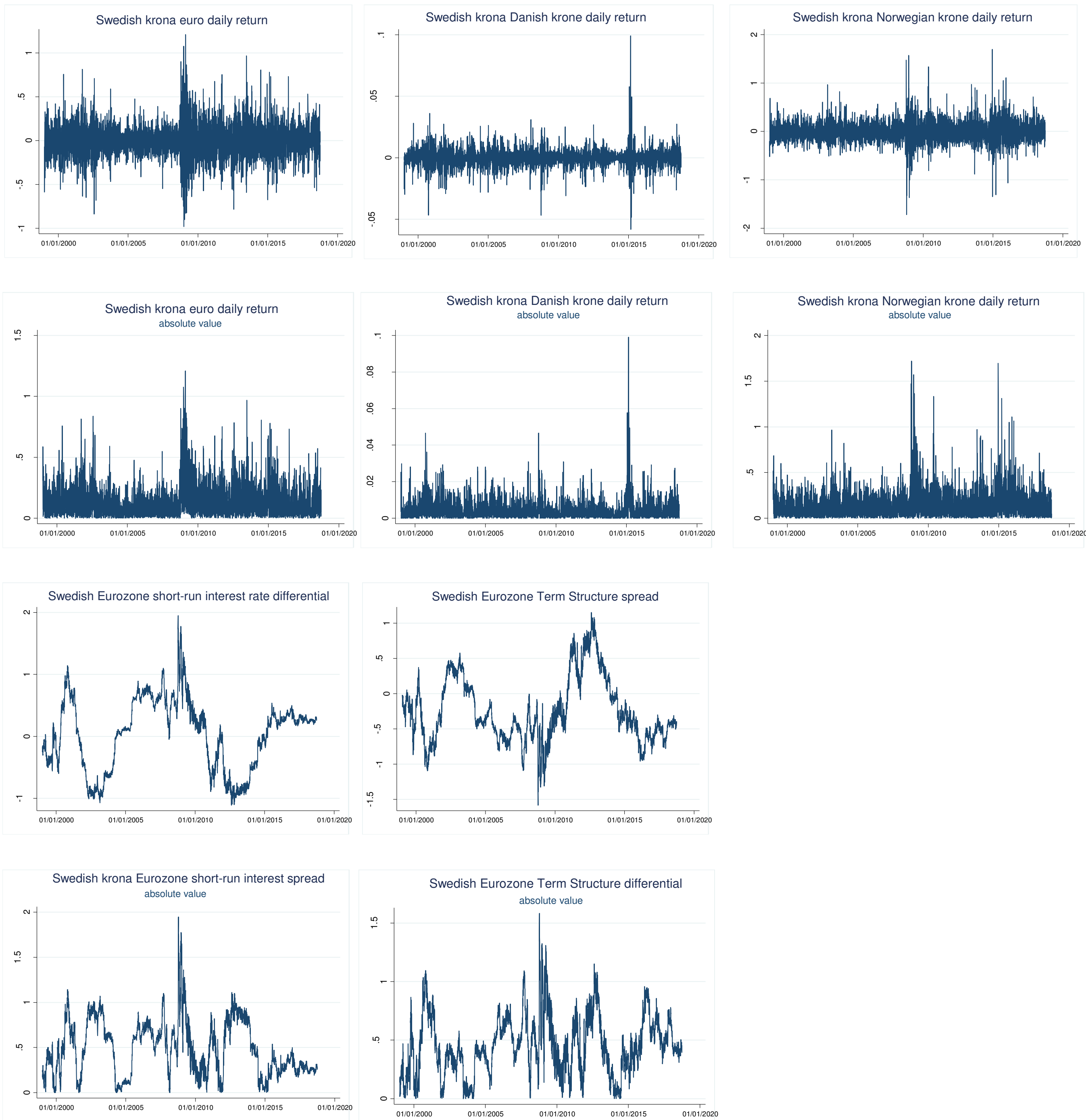
where H_t^2 is the Cholesky factor of the time-varying conditional covariance matrix H_t; D_t is a diagonal matrix of conditional variances; C_t is a matrix of conditional quasicorrelations; and λ_1 and λ_2 are nonnegative adjustment parameters that manage the dynamics of the conditional quasicorrelations. λ_1 measures how much the correlation depends on shocks. λ_2 measures how much the correlation depends on its own lag. If a Wald test fails to reject the null hypothesis, $\lambda_1 = \lambda_2 = 0$, then the conditional correlation does not vary over time and the Constant Conditional Correlation MGARCH is the correct process specification. If a Wald test rejects the null hypothesis, then the conditional correlation varies over time and the DCC MGARCH is the correct process specification. For this study, the Wald test rejected the null hypothesis so the DCC MGARCH approach is used. A sizable correlation indicates interaction between the two equations' error processes. The size and significance of the λ_1 and λ_2 parameters indicate whether the evolution of the conditional covariances depend more on their past values or on the lagged residual's innovations. When $\lambda_2 > \lambda_1$, then the conditional covariances depend more on their own past values rather than on the lagged residuals' innovations.

3. Data

This study uses daily data from 4 January 1999 through 30 September 2018. The daily Swedish krona-euro exchange rate, Swedish krona-Danish krone exchange rate, and the Swedish krona-Norwegian krone exchange rate were collected, and log daily returns calculated. The central banks are the sources of the daily exchange rate data. Figure 1 presents graphs of the log return and the absolute value of the log return for the three exchange rates. The graphs suggest that all three exchange rates experienced volatility clustering with the greatest volatility at the beginning of the financial crisis and the introduction of NNIR.

Since an outcome of the Riksbank non-traditional monetary policy was to lower both short-term and long-term interest rates during the crisis (Elmér et al. 2012), both the short-term interest rate differential and the term structure differential were calculated for Sweden and the eurozone. The daily 3-month Treasury Bill rate (3M) and the daily 10-year bond rate (10Y) for Sweden and the eurozone were collected from the Riksbank and the European Central Bank. The Sweden-eurozone short-run interest rate differential (SRSpread) = (3M euro – 3M Swedish) and the Sweden-eurozone term structure differential (TermSpread) = [(10Y euro – 3M euro) – (10Y Swedish – 3M Swedish)]. As shown in Figure 1, the SRSpread peaked in 2009 while the TermSpread peaked in 2015. The variability of both the SRSpread and the TermSpread appear to have stabilized after the central banks implemented the negative nominal interest rate policies.

Figure 1: Log return and absolute value log return for the Swedish krona-euro, Swedish krona-Danish krone, and Swedish krona-Norwegian krone exchange rates, and the log return and absolute log return for the short-run interest rate differential and term- structure differential for Sweden and the eurozone



For both the EGARCH and DCC MGARCH approaches, the SKE is the dependent variable and the SRSpread and the TermSpread are independent variables. Dummy variables identifying non-traditional monetary policy time periods are used to access possible changing policy effects. The period before July 2009 is the non-traditional monetary policy period (preNTM), the period July 2009 and after is the non-traditional monetary policy period (NTM), and the period February12, 2015 and after is the non-traditional monetary policy with negative interest rates period (NTM-NNIR). To capture possible correlation of volatility across exchange rate markets, the Swedish krona-Danish krone return (SKDK), and Swedish krona-Norwegian krone return (SKNK) are additional independent variables in the DCC MGARCH approach.

4. Results

The first step to support using the GARCH approaches is to test the null hypothesis of homoscedasticity and a normal distribution. Examining the SKE data, Figure 2 shows evidence of volatility clustering. Periods of low volatility are followed by periods of low volatility and periods of high volatility are followed by periods of high volatility. The significant White test reported in Table II supports the evidence of heteroskedasticity shown in Figure 2. Figure 3 shows evidence of kurtosis and skewness. The kurtosis test reported in Table II is positive and greater than 3 supporting the Figure 3 evidence that the distribution has heavier tails and a sharper peak than a normal distribution. The positive skewness value reported in Table II also suggests an asymmetric distribution with a long tail to the right. The test results in Table II confirm that the SKE are not normally distributed and exhibit volatility clustering. The LM test indicates the presence of significant ARCH effects. These results reject the null hypothesis and support the use of the GARCH approaches.

Figure 2: Evidence of volatility clustering.

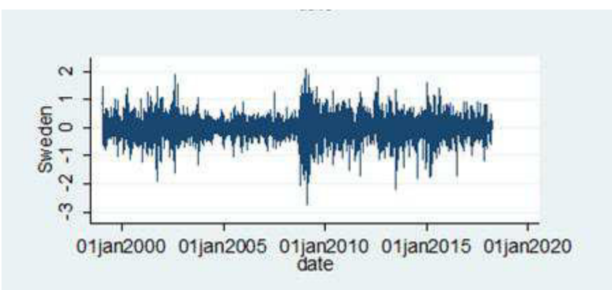


Figure 3: Evidence of Kurtosis and Skewness

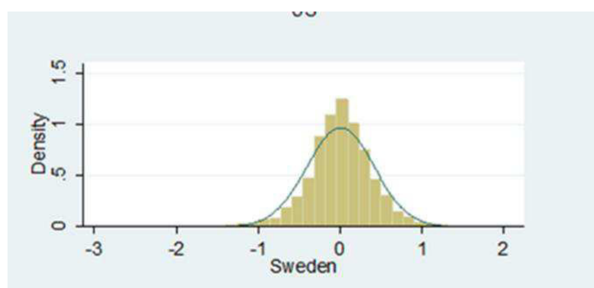


Table II: Tests for evidence of ARCH

Test	Results
White	98.46***
Skewness	8.52**
Kurtosis	6.75***
LMtest	145.683***

4.1 EGARCH approach results

Table III reports the EGARCH approach results that assess the influence non-traditional monetary policies have on SKE volatility. The independent variables used are the SRSpread and the TermSpread during the three time periods, preNTM, NTM, and NTM-NNIR. As implied by efficient market theory, the mean equations indicate the lagged daily returns and the interest rate differentials are not significant determinants of current exchange rate returns regardless of the time period. The non-traditional monetary policies did not significantly influence exchange rate returns or interfere with market efficiencies.

Table III: The EGARCH approach results for the Swedish krona-euro exchange rate volatility. The results are based on daily data from 4 January 1999 through 30 September 2018.

Mean equation	SKE and SRSpread			SKE and TermSpread		
ρ	.0051 (.0037)			-.0058 (.0046)		
ρ preNTM		.0081 (.0051)	.0086 (.0054)		-.0098 (.0066)	-.0108 (.0068)
ρ NTM		.0002 (.0054)	-.0031 (.0059)		-.0018 (.0058)	.0084 (.0065)
ρ NTM NNIR			.0241 (.0027)			-.0195 (.0125)
μ	.0009 (.0023)	.0006 (.0232)	-.0009 (.0027)	-.0040 (.0025)	-.0008 (.0026)	-.0017 (.0031)
Variance						
Ω	-3.537*** (.0221)	-3.529*** (.0225)	-3.461*** (.0252)	-3.555*** (-.1071)	-3.528*** (.0248)	-3.404*** (.0190)
ϒ	.0609*** (.0218)	.0648*** (.0222)	.0611*** (.0228)	.0654*** (.0210)	.0732*** (.0215)	.0845*** (.0163)
α	.3699*** (.0348)	.3645*** (.0348)	.3608*** (.0352)	.3762*** (.0341)	.3687*** (.0342)	.3580*** (.0257)
β	.1613*** (.0285)			-.1071*** (.0376)		
β preNTM		.0331 (.0380)	.0141 (.0395)		.1691*** (.0485)	.2051*** (.0306)
Β NTM		.2951*** (.0404)	.4010*** (.0439)		-.2825*** (.0477)	-.5382*** (.0365)
β NTM-NNIR			-.7195*** (.1093)			1.1289*** (.0888)
Observations	5,038	5,038	5,038	5,038	5,038	5,038

The mean equation dependent variable is Swedish krona-euro exchange rate return and the variance equation dependent variable is the Swedish krona-euro exchange rate return variance. The independent variables for both equations include the SRSpread, the TermSpread, and dummy variables for the preNTM period, NTM period, and NTM-NNIR period. *** significant at .01; ** significant at .05; * significant at .10.

The SRSpread variance equations reveal that the SRSpread significantly influenced SKE volatility, and that influence changed during the three time periods. The weighted long-run variance, ϒ, is positive and significant. This suggests that SKE appreciation is more destabilizing than SKE depreciation. As expected, the positive and significant GARCH error coefficient, α, is evidence of volatility clustering. The SKE experiences periods of high volatility followed by periods of high volatility, and periods of low volatility followed by periods of low volatility. The GARCH lag coefficient, β, assesses the persistence of the volatility decay and any significant differences between the three time periods. Without accounting for the three time periods, the positive and significant β suggests that the persistence of volatility decayed slowly over time. But when comparing the preNTM and NTM periods, the results reveal that the slow decay was driven by the NTM period and not the preNTM. The positive but insignificant β preNTM suggests that volatility decayed rapidly and did not persist prior to 2009. This changed during the NTM time period. The positive and significant β NTM reveals that SKE volatility decayed more slowly during the NTM period. The results changed again once the Riksbank's introduced the NNIR policy. When adding the NNIR time period, the negative and significant β NTM-NNIR indicates improved reversion toward long-run average volatility during the NTM NNIR period. These results suggest that while the introduction of the non-traditional monetary policy slowed the persistence of volatility decay, the use of NNIR reduced the influence and persistence short-term interest rate differential changes had on SKE volatility.

A goal of the Riksbank non-traditional monetary policy was to influence both short-term and longer-term interest rates. While the TermSpread did not significantly influence the mean equation, the TermSpread significantly influenced SKE volatility. Similar to the SRSpread results, the weighted long-run variance, ϒ, is positive and significant indicating SKE appreciation is more destabilizing than SKE depreciation. The positive and significant GARCH error coefficient, α, is evidence of volatility clustering. In contrast to the SRSpread results, the negative and significant β NTM suggests the non-traditional monetary policy reduced the persistence of volatility arising from the TermSpread. The introduction of NTM reduced the influence and persistence the TermSpread had on SKE volatility. The β NTM-NNIR is positive and significant suggesting that the Riksbank's introduction of the NNIR policy slowed the decay of volatility gains arising from the term structure interest rate differential during NTM period.

4.2 DCC MGARCH results

The purpose for using the DCC MGARCH approach is to investigate the potential interdependence of volatility across markets by allowing for the conditional covariances of the errors to follow an autoregressive moving average structure. In this study, the DCC MGARCH approach captures the interdependence of volatility or spillover effects related to the exchange rate returns of two main trade partners, Swedish krona–Denmark krone returns (SKDK) and Swedish krona–Norwegian krone returns (SKNK). Denmark and Norway operate under two different types of exchange rate regimes. Denmark has maintained the ERM II exchange rate regime with the euro since 1999 while Norway has maintained a floating exchange rate system since 1992.

As reported in Table IV, the DCC MGARCH approach results find evidence of spillover effects across the exchange rate markets. For all variance equations, α_{SKKr} and β_{SKKr} for both SKDK and SKNK are positive and significant revealing interdependence of volatility across the exchange rate markets. The sum of α_{SKKr} and β_{SKKr} for both SKDK and SKNK are large, indicating considerable time-varying co-movement. For SKNK, the sum of α_{SKKr} and β_{SKKr} is close to unity, indicating highly persistent conditional correlation. These results suggest possible elevated contagion risks during times of volatility and market shocks, and the contagion risks tend to decay slowly especially for SKNK. The magnitudes of λ_1 and λ_2 indicate that the evolution of the conditional covariances depend more on their past values than on the lagged residuals. The dynamic process appears to be mean reverting.

Table IV: The DCC MGARCH approach results. The results are based on daily data from 4 January 1999 through 30 September 2018.

	Danish krone				Norwegian krone	
Mean	SRSpread		TermSpread		SRSpread	
ρ preNTM	.0070 (.0054)	.0077 (.0056)	-.0094 (.0073)	-.0117 (.0077)	.0089* (.0051)	.0095* (.0052)
ρ NTM	-.0038 (.0066)	-.0067 (.0074)	.0002 (.0067)	.0062 (.0088)	-.0042 (.0059)	-.0028 (.0065)
ρ NTM-NNIR		.0294 (.0222)		-.0202 (.0143)	.0003 (.0022)	.0199 (.0211)
μ	.0004 (.0024)	-.0020 (.0028)	-.0047 (.0027)	-.0034 (.0032)		-.0004 (.0025)
Variance						
s_{SKE}	-3.733*** (.0303)	-3.648*** .0324	-3.739*** (.0317)	-3.626*** (.0336)	-3.637*** (.0300)	-3.621*** (.0321)
α_{SKE}	.2428*** (.0258)	.2247*** (.0248)	.2555*** (.0259)	.2301*** (.0248)	.2214*** (.0243)	.2073*** (.0235)
β_{SKE} preNTM	.0781 (.0525)	.0568 (.0527)	.1652** (.0722)	.2685*** (.0728)	.1121** (.0487)	.0963** (.0489)
β_{SKE} NTM	.2749*** (.2749)	.3895*** (.0563)	-.2735*** (.0586)	-.5538*** (.0668)	.2438*** (.0488)	.3258*** (.0505)
β_{SKE} NTM-NNIR		-.7285*** (.1139)		1.144*** (.1326)		-.6810*** (.1120)
α_{SKKr}	.3577*** (.0319)	.3573*** (.0319)	.3577*** (.0319)	.3576*** (.0319)	.2044*** (.0202)	.2046*** (.0203)
β_{SKKr}	.4471*** (.0476)	.4466*** (.0477)	.4461*** (.0477)	.4468*** (.0477)	.6678*** (.0745)	.6796*** (.0753)
Correlation	.0125 (.0210)	.0533*** (.0160)	.0562*** (.0160)	.0556*** (.0160)	.39945*** (.0390)	.4171*** (.0417)
λ_1	.0005 (.0009)	.0216** (.0100)	.0224** (.0102)	.0214** (.0097)	.0204*** (.0033)	.0220*** (.0033)
λ_2	.9962*** (.0019)	.7669*** (.1177)	.7564*** (.1219)	.7673*** (.1149)	.9689*** (.0045)	.9678*** (.0043)
Observations	5,038	5,038	5,038	5,038	5,038	5,038

The mean equation dependent variable is the Swedish krone-euro exchange rate return and the variance equation dependent variable is the Swedish krone-euro exchange rate return variance. The independent variables are SRSpread, TermSpread, SKDK, SKNK, and dummy variables for the preNTM period, NTM period, and NTM-NNIR period. SKE is the Swedish krona-euro return and SKKr is the Swedish krona-krone exchange rate return for either the Danish krone (columns 2-5) or the Norwegian krone (columns 6-7). The DCC MGARCH TermSpread equations did not converge. *** significant at .01; ** significant at .05; * significant at .10.

When examining the influence of the Swedish krona-Danish krone exchange rate, the remaining DCC MGARCH results are similar to the EGARCH results. The mean equation results indicate the lagged daily returns and the interest rate differentials are not significant determinants of current exchange rate returns, suggesting the non-traditional monetary policies did not significantly influence exchange rate returns or interfere with market efficiencies. The variance equation results indicate SKE appreciation was more destabilizing than SKE depreciation. The variance equation results also suggest the introduction of the non-traditional NNIR monetary policy reduced the influence and persistence short-term interest rate differential changes had on

SKE volatility while NNIR reduced the influence and persistence term structure interest rate differential changes had on SKE volatility.

When examining the influence of the Swedish krona-Norwegian krone exchange rate, three of the DCC MGARCH approach results differ from the EGARCH approach results. First for the SRSpread mean equation, ρ preNTM is positive and significant at 10%. Although 10% is a lenient threshold, the significance of the variable violates the efficient market theory. While this paper does not explore the reasons behind the evidence of market inefficiency, a possible reason is that the Norwegian krone is primarily a regional currency and therefore its adjustment period is prolonged. Second, in the variance equation the GARCH lag coefficient, β_{SKE}, which assesses the persistence of the volatility, although near zero is positive and significant for the preNTM period. This result suggests that the persistence of volatility decayed with a short delay during the preNTM period once SKNK spillover effects are included. The remaining SRSpread variance equation results are consistent with previous results. SKE appreciation is more destabilizing than SKE depreciation and the non-traditional NNIR policy reduced the influence and persistence the short-term interest rate differential changes had on SKE volatility. Third when including the TermSpread, the results did not converge and were therefore not reported for the Norwegian krone. A likely reason for non-convergence is that the DCC GARCH approach as specified does not fit the data.

5. Conclusion

In response to the global financial crisis and lack of conventional monetary policy effectiveness, the Riksbank introduced non-traditional monetary policy tools to restore financial market stability. Using the EGARCH and DCC MGARCH approaches, this study found non-traditional monetary policies and the potential interdependence of exchange rate markets influenced the persistence of SKE volatility associated with the SRSpread and TermSpread differently. Prior to implementing NTM, persistence of volatility associated with SRSpread was not evident. Once NTM was implemented, the persistence of volatility decay associated with SRSpread increased until the NTM-NNIR period. The results suggest that removing the 0% bank rate lower bound constraint, reduced the persistence of volatility arising from short-term interest rate spreads and improved exchange rate market stability. During the NTM period, persistence of volatility associated with TermSpread decay improved but then slowed during the NTM-NNIR period. The TermSpread results suggest that while implementing NTM reduced the persistence of volatility associated with term structure spread, removing the 0% bank rate lower bound constraint increased the persistence of volatility associated with term structure spread. The results also revealed the Swedish krona-Danish krone return and Swedish krona-Norwegian krone return exhibited large conditional correlations or spillover effects on SKE volatility. The large interdependence of the exchange rates suggest that contagion risks were elevated during the periods of high volatility and market shocks. The results, 0% bank rates are linked to slower volatility decay associated with TermSpread and highly persistent conditional correlation and slow decay are associated with elevated risk of contagion, conflict with the goal of financial market stability. Further research is needed to identify the underlying factors influencing these results.

When estimating a GARCH approach, market efficiency requires the mean equation parameters be insignificant, implying that the independent variables do not significantly influence Swedish krona-euro exchange rate returns. The mean equation results for all GARCH approaches supported efficient markets results, except for the DCC MGARCH approach when examining the interdependence of SKNK and SKE volatility. At a 10% level of confidence, which is a lenient threshold, the parameter for the preNTM period is positive and significant. While this study does not explore the reasons behind the evidence of market inefficiency, a possible reason is that the Norwegian krone is primarily a regional currency and therefore its adjustment period is prolonged. This as well as identifying potential market inefficiencies arising from interdependence of regional exchange rates are prospects for future research.

6. References

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