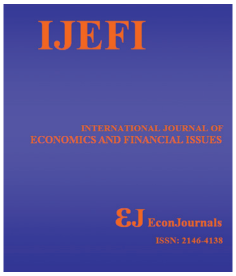

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Toda-Yamamoto Causality Test between Inflation and Nominal Interest Rates: Evidence from Three Countries of Europe

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ABSTRACT

This paper investigates the relationship between inflation and nominal interest rates for three European countries, Germany (member of EMU), Great Britain (member country of EU but not EMU) and Switzerland (a non-EU country) from January 1995 until May 2015. For testing the long run equilibrium relationship we use the autoregressive distributed lag (ARDL) cointegration technique (ARDL) developed by Pesaran et al. (2001) as well as Granger no-causality approach developed by Toda and Yamamoto (1995) in a two-variable vector autoregression model. The results of ARDL approach (bound test) shown that there is a cointegrated vector for the three examined countries thus Fisher assumption is valid. Finally, the results of Toda and Yamamoto approach show that the nominal interest rate has a positive relationship and affects inflation on a large scale in the three countries that we study, while inflation influences interest rate only in Germany.

Keywords: Fisher Effect, Autoregressive Distributed Lag Cointegration Test, Error Correction Model, Toda-Yamamoto Causality Test
JEL Classifications: C32, E23, O11

1. INTRODUCTION

Irving Fisher on 1930 in his book entitled "The Theory of Interest" has drawn the attention of scientists and his book is regarded one of the most discussed issues that have been examined in the field of economics. The assumption that nominal interest rate is regarded, ceteris paribus, the cornerstone for expected inflation comes across in many theoretical models of monetary policy. Because of the variations on money value reallocating the purchasing power between borrowers and lenders, an answer to nominal interest rate on inflation changes and profits' reallocation is to stabilize real interest rate. This phenomenon is the strong form on Fisher's assumption. However, this is valid for countries with no taxes. Darby (1975) and Feldstein (1976) have shown that due to taxation, nominal interest rates should change often from changes of expected inflation (Weidmann, 1997).

Fisher assumption (1930) that nominal interest rate is connected with the expected inflation rate has been discussed in many empirical studies. The real interest rate is an important factor both for household savings and companies investments. Also, this relationship has serious effects on monetary policymakers, given that inflation's expectations can affect the nominal interest rate directly. Furthermore, the validity on Fisher's result has important effects for monetary policy and must be examined from central banks.

The aim of this paper is to examine the long run consequences on Fisher's assumption in three different European countries which are characterized from changes on nominal interest rates. This study differs in two ways. Firstly, it uses recent data covering the period from 1960 to 2015. Secondly for variable causality, the Toda and Yamamoto approach is used.

The rest of the paper is as follows: Section two provides the literature review. The methodology and data are described on section three. Empirical results are given on section four while conclusions and policy implications are provided in the last section.

2. LITERATURE REVIEW

Fisher's hypothesis (1930) has been examined for many countries and the results given differed from country to country during particular time periods. For example, the relationship between nominal interest rate and expected inflation rate was found to be strong for USA, Canada and United Kingdom on the post-war period until 1979. After 1979, this relationship was not so strong (Mishkin, 1984). Various explanations have been given for the seemingly inconsistency on Fisher's hypothesis. The most important are the following:

- Insufficient measures of inflation expectations.
- The need to discriminate between short and long run results on shifts of expected inflation.
- Tax policy.
- Crowder and Hoffman (1996) claim that the choice of econometric methodologies is responsible for the ambiguous results.

There were many important studies for many countries and the most recent are referred below:

Mishkin and Simon (1995) examined the short and long run results of Fisher's hypothesis in Australia using quarterly data for the period 1962 until 1993. The results of their study showed that while a long run effect on Fisher's hypothesis seems to exist, there is no evidence that this hypothesis is valid in the short run.

Weidmann (1997) examined the long run relationship between nominal interest rate and inflation in Germany using monthly data from January 1967 until June 1996. The result of the study showed that interest rates cannot fully adjust on inflation's shifts. Thus, Fisher's hypothesis is rejected.

Rapach (2003) using a structural vector autoregression (VAR) analyzed the outcomes of inflation-interest rate relationship in 14 industrial countries using annual data. The results of his paper showed that in the long run, Fisher's hypothesis is rejected for all countries. Also, using quarterly data, he reached the same conclusion that Fisher's hypothesis is rejected for four out of five examined countries.

Westerlund (2008) analyzed Fisher's hypothesis for a group of 20 OECD countries using quarterly panel data from 1980 until 2004. Westerlund suggested two new cointegration tests based on Durbin-Hausman that can be applied under general terms. The outcomes of the paper showed that Fisher's hypothesis cannot be rejected if cointegration exists on panel data.

Beyer et al. (2009) applied new structural tests in order to examine Fisher hypothesis on a non-linear cointegrating relationship for 15 OECD countries. The results of their paper presented a cointegrated relationship for linear models, thus Fisher's hypothesis is valid on these models.

Finally, Hatemi (2009) examines data for USA and United Kingdom for the period 1964 until 2007 using montly data. Employing the bootstrap method – the structural break is October 1987 (stock market crash) - he finds that whilst there was a defeat on stock markets, Fisher's hypothesis was not disrupted on both markets.

3. DATA AND METHODOLOGY

For interest rate and inflation time series we use monthly data in percentage for the three countries. Sample size covers the period from January 1995 until May 2015. Inflation rates are proxied on consumer price index variations. All data derive from OECD database.

Fisher (1930) determined the following relationship among nominal interest rate, real interest rate and inflation:

$$i_t = r_t + \pi_t^e \quad (1)$$

Where:
i_t = Nominal interest rate.
r_t = Real interest rate.
π_t^e = Expected inflation rate.

Using rational expectations model we can highlight that the difference between real and nominal inflation rate is given in the following equation:

$$\pi_t - \pi_t^e = \varepsilon_t \quad (2)$$

Where:
π_t = Actual inflation.
ε_t = Error term.

If the rational expectations model is used on Fisher's equation, then we get the following:

$$i_t = r_t + \pi_t \quad (3)$$

Equation (2) can be expressed as such:

$$\pi_t = \pi_t^e + \varepsilon_t \quad (4)$$

Where:
ε_t = White noise.

If we assume that real interest rate depends from expected interest rate then we get the following stationary process:

$$r_t = r_t^e + u_t \quad (5)$$

Where:
u_t = White noise.

If we replace equations (4) and (5) on equation (3) we get:

$$i_t = r_t + \pi_t = r_t^e + u_t + \pi_t^e + \varepsilon_t = r_t^e + \pi_t^e + v_t \quad (6)$$

Where:
$v_t = u_t + \varepsilon_t$ = White noise

Equation (6) can be expressed as such:

$$i_t = c + \beta\pi_t^e + v_t \quad (7)$$

Where:
c = Long run real interest rate.

If $\beta = 1$, then we get the strong form on Fisher's assumption, if $\beta < 1$ then we get the weak form on Fisher's assumption.

Literature, based on unit roots and cointegration provided an important boost for the empirical test on Fisher's assumption. It has been claimed that from empirical literature both interest rates and inflation are non-stationary time series (Engle and Granger, 1987; Campbell and Shiller, 1987; Mishkin, 1992; Crowder and Hoffman, 1996). Thus, time series should be examined for their stationarity.

3.1. Order of Integration

In this section, we test for integration order of the time series. For this testing we use Augmented Dickey-Fuller (ADF) test, Phillips-Perron test as well as Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test.

3.2. Cointegration Tests

Afterwards, we examine if the nominal interest rate and expected inflation rate are cointegrated and share a common stochastic trend. Cointegration analysis is a useful tool in order to examine if there exists a long run equilibrium relationship between two or more time series. This means that an increase on nominal interest rate is connected with an increase on expected inflation in the long run. In other words, the existence of a cointegrated vector demands Fisher's assumption. For the examination of Fisher's assumption, we adopt the autoregressive distributed lag cointegration technique (ARDL) developed by Pesaran et al. (2001) for the following reasons:

- Only one single equation is used.
- It can be used in series that are not integrated same order, as long as there will be no series order two I(2) (Pesaran et al., 2001).
- It allows the series to have different optimal lags.

3.3. ARDL Cointegration Analysis

We continue testing for long run relationships between the examined variables for the three countries using ARDL approach which developed by Pesaran et al. (2001). ARDL test presupposes the estimation of the following unrestricted error correction model.

$$\Delta y_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta x_{t-j} + \phi_1 y_{t-1} + \phi_2 x_{t-1} + e_t \tag{8}$$

Where Δ denotes the first difference operator, and e_t is error term.

The ARDL (p,q) approach consists of a procedure with the following stages:

- We choose the maximum values for lags p and q of the unrestricted error correction model using the minimum values on Akaike Information Criterion (AIC), Schwarz (SBC), Hannan-Quinn (HQC) criteria.
- A prerequisite on ARDL model on equation (8) is that errors are serially independent (should not be autocorrelated). Pesaran et al. (2001), on page 308, mention that this assumption is important for choosing the maximum number lags.
- When errors on equation (8) are independent, we continue on testing the dynamic stability of ARDL model using the unit circle.
- Meanwhile, we apply the bounds test on equation (8). This test uses the F distribution and the null hypothesis of no cointegration is the following:
  $H_0: \varphi_1 = \varphi_2 = 0$ (No cointegration).

Against the alternative hypothesis of cointegration
  $H_1: \varphi_1 \neq \varphi_2 \neq 0$ (cointegration)

- If bounds testing lead us to cointegration we can estimate the long run relationship of series on equation (9) as well as the restricted error correction model from equation (10).

$$y_t = \alpha_0 + \alpha_1 x_1 + u_t \tag{9}$$

$$\Delta y_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta x_{t-j} + \vartheta z_{t-1} + \varepsilon_t \tag{10}$$

Where p and q are order lags on y_t and x_1 variables respectively, z_t is the error term created by cointegrating regression (equation 9).

3.4. Testing Stability in ECM

The existence of dynamic restricted error correction model derived by equation (10) does not necessarily imply that the estimated coefficients are stable. Thus, Pesaran et al. (1995, 2001) suggested the stability test of estimated parameters on estimated models of Brown et al. (1975) known as cumulative sum (CUSUM) and cumulative square sum (CUSUMSQ).

3.5. Causality Analysis

One of the advantages of VAR models is that we can detect causality direction. This direction is highly important for central banks all over the world because they adjust their monetary policy. In this paper, we adopt causality testing of Toda and Yamamoto (1995) in comparison to Granger test for the following reasons:

- Granger testing can give spurious regressions on functions with time lags on integrated variables.
- F statistic can be used only when variables are cointegrated.
- The error correction model stated by Engle and Granger (1987) and VAR model stated by Johansen and Juselius (1990) and Johansen (1991) as an alternative way for testing causality are cumbersome.
- Toda and Phillips (1993) on their paper claimed that Granger causality with the error correction model can lead to wrong conclusions due to the dependence of parameters which might be asymptotic in some cases.
- Finally, according to Rambaldi and Doran (1996), Toda and Yamamoto test for Granger non-causality is conducted from modified Wald test (MWald) and in Seemingly Unrelated Regression models (SUR models).

3.5.1. Toda –Yamamoto causality analysis

In this section, we examine causal relationship between nominal interest rate and inflation rate using seemingly unrelated regression model with two variables. If interest rates and inflation rates have a common stochastic trend, then is it expected to have a causal relationship between these two time series.

Toda and Yamamoto (1995) in order to investigate Granger causality (1961), they developed a method based on the estimation of augmented VAR model ($k+d_{max}$) where k is the optimal time lag on the first VAR model and d_{max} is the maximum integrated order on system's variables (VAR model). The Toda and Yamamoto approach follows the steps below:

- We find the integration order for each series. If the integration order is different we get the maximum (d_{max}).
- We create a VAR model on series levels regardless of integration order that we found.
- We define the order of VAR model (k) from lag length taken from LR, final prediction error (FPE), AIC, SC, HQ criteria.
- We test if VAR ($k+d_{max}$) (adjusted VAR model) is correctly specified.
- If series have the same integration order then we continue on cointegration test using Johansen methodology. Otherwise, we employ Pesaran et al. (2001) approach.
- No matter what the result will be on cointegration, we continue with causality test.
- We get VAR ($k+d_{max}$) model using suitable lags for every equation of the system.
- We apply Granger causality test for non-causality using pairwise equations and modified Wald test (MWald) for the significance of parameters on examined equations on number time lags ($k+d_{max}$).
- The modified Wald test (MWald) follows Chi-square (χ^2) distribution asymptotically and the degrees of freedom are equal to the number of time lags ($k+d_{max}$).
- Rejection of null hypothesis entails the rejection of Granger causality.
- Finally, we check if there is cointegration on VAR model.
- If two or more series are cointegrated, then there is one causal relationship (unidirectional or bilateral) but not vice versa.

VAR model of Toda and Yamamoto causality is set up as follows:

$$y_t = \mu_0 + \left(\sum_{i=1}^{k} \alpha_{1t} y_{t-i} + \sum_{i=k+1}^{d_{max}} \alpha_{2t} y_{t-i} \right) + \left(\sum_{i=1}^{k} \beta_{1t} x_{t-i} + \sum_{i=k+1}^{d_{max}} \beta_{2t} x_{t-i} \right) + \varepsilon_{1t} \quad (11)$$

$$x_t = \phi_0 + \left(\sum_{i=1}^{k} \gamma_{1t} x_{t-i} + \sum_{i=k+1}^{d_{max}} \gamma_{2t} x_{t-i} \right) + \left(\sum_{i=1}^{k} \delta_{1t} y_{t-i} + \sum_{i=k+1}^{d_{max}} \delta_{2t} y_{t-i} \right) + \varepsilon_{2t} \quad (12)$$

Where k is the optimal time lag on the initial VAR model and d_{max} is the maximum integration order on variables system (VAR model).

4. EMPIRICAL RESULTS

4.1. Order of Integration

The preliminary stage of the paper defines the order of integration for each time series. For this reason, we use a number of tests for interest rate and inflation presented on Table 1.

The results on Table 1 reveal that series indicate a different integration order for the three countries. Interest rate series are integrated order null I(0) while inflation rate series are integrated first order I(1). Therefore, we examine the long run relationship for each pair of series for the examined countries using Pesaran et al. (2001) methodology, the ARDL.

4.2. ARDL Bounds Testing Approach

From model (8) we find the maximum values for p and q lags, using FPE, AIC, Schwarz Information Criterion (SIC), HQC, and likelihood ratio (LR) criteria. The results of these criteria are presented on Table 2.

Table 1: Univariate unit root tests

Variables	ADF		P-P		KPSS	
	Const	Const, trend	Const	Const, trend	Const	Const, trend
Level						
INTG	−1.343 (1)	−3.215 (1)^	−1.315 [6]	−3.043 [6]	1.899 [11]	0.174 [11]
INTUK	−1.872 (3)	−3.281 (3)^	−1.889 [6]	−2.940 [6]	1.677 [12]	0.179 [11]
INTSW	−1.247 (0)	−2.540 (0)	−1.395 [5]	−2.990 [6]	1.810 [11]	0.175 [11]
INFG	−3.109 (1)+	−3.089 (1)	−21.83 [12]*	−21.77 [12]*	0.048 [19]*	0.049 [19]*
INFUK	−2.308 (12)	−2.305 (12)	−16.75 [13]*	−16.80 [14]*	0.283 [14]*	0.143 [15]+
INFSW	−3.252 (11)+	−3.66 (11)+	−13.83 [76]*	−15.07 [56]*	0.414 [77]*	0.129 [71]+
First differences						
ΔINTG	−11.33 (0)*	−11.31 (0)*	−11.34 [4]*	−11.32 [4]*	0.069 [6]*	0.068 [6]*
ΔINTUK	−7.191 (2)*	−7.201 (2)*	−12.07 [5]*	−12.08 [5]*	0.106 [6]*	0.060 [6]*
ΔINTSW	−14.64 (0)*	−14.61 (0)*	−14.71 [4]*	−14.74 [4]*	0.068 [5]*	0.069 [5]*
ΔINFG	−13.13 (10)*	−13.1 (10)*	−136.8 [53]*	−136.0 [53]*	0.072 [36]*	0.065 [36]*
ΔINFUK	−8.827 (11)*	−8.82 (11)*	−91.61 [33]*	−91.27 [33]*	0.066 [34]*	0.064 [34]*
ΔINFSW	−10.85 (10)*	−10.8 (10)*	−51.73 [26]*	−51.54 [26]*	0.226 [41]*	0.131 [41]+

INTG, INTUK, INTSW show the interest rates for Germany, United Kingdom and Switzerland respectively. Δ denotes on first differences of series, ^, +, *denotes rejection of null hypothesis at the 10%, 5% and 1% level of significance, respectively. The numbers within parentheses for the ADF statistics represents the lag length of the dependent variable used to obtain white noise residuals. The lag lengths for ADF equation were selected using AIC (Akaike, 1974). The numbers within brackets for the PP and KPSS statistics represent the bandwidth selected based on Newey and West (1994) method using Bartlett Kernel. AIC: Akaike Information Criterion, ADF: Augmented Dickey-Fuller, PP: Phillips-Perron, KPSS: Kwiatkowski, Phillips, Schmidt, and Shin

Table 2: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SBC	HQC
Germany						
0	95.040	NA	0.0274	−0.7586	−0.7006	−0.7352
1	103.80	17.157*	0.0257	−0.8233	−0.7508*	−0.7941*
2	104.50	1.3664	0.0257	−0.8208	−0.7338	−0.7857
3	106.28	3.4622	0.0255*	−0.8273*	−0.7258	−0.7864
4	106.30	0.0354	0.0258	−0.8191	−0.7031	−0.7724
United Kingdom						
0	70.065	NA	0.0337	−0.5505	−0.4925	−0.5271
1	75.956	11.536	0.0324	−0.5913	−0.5187	−0.5620
2	78.103	4.1864	0.0321	−0.6008	−0.5187	−0.5620
3	83.316	10.122*	0.0309*	−0.6359*	−0.5344*	−0.5950*
4	83.516	0.3861	0.0312	−0.6293	−0.5132	−0.5825
Switzerland						
0	108.78	NA	0.0248	−0.8565	−0.7695	−0.8214
1	108.74	1.8309*	0.0246*	−0.8645*	−0.7920*	−0.8353*
2	109.38	1.1733	0.0249	−0.8532	−0.7517	−0.8123
3	110.33	0.0766	0.0249	−0.8527	−0.7367	−0.8060
4	110.33	0.0003	0.0251	−0.8444	−0.7139	−0.7918

*Denotes the optimal lag selection, AIC: Akaike Information Criterion, HQC: Hannan-Quinn criteria, FPE: Final prediction error

Results on Table 2 show the maximum time lag is 1 for Germany and Switzerland and 3 for United Kingdom. The order of optimal lag length on equation (8) is chosen from the minimum value of AIC, SBC and HQC criteria. On Table 3 the results of these criteria are presented.

The results on Table 3 show that ARDL (1,0) is the most suitable for Germany and Switzerland and ARDL (1,2) is most suitable for United Kingdom.

Followed, we test for error independence (LM test) until first order for Germany and Switzerland and third order for United Kingdom (maximum lag number). The following Table 4 presents this test.

The results on Table 4 show that errors are not autocorrelated on our examined models. Then we follow on with the test of dynamic stability of the models. This test is performed with the unit circle. If the reverse roots on equation (8) are within the unit cycle then the models are characterized as dynamically stable.

The results of Figure 1 show that there is a dynamic stability of models on the three countries, because all roots are inside the unit circle.

It was necessary, before proceeding to the bounds testing, to present the actual and fitted residuals of unrestricted ECM of ARDL (1,0) and ARDL (1,2) equations on the three countries (Figure 2).

Afterwards, we conduct the ARDL bounds testing approach of cointegration according to Pesaran et al. (2001). In other words, we test if φ_1 and φ_2 parameters in equation (8) are null on our estimated models.

The results on the Table 5 show that the value of F-statistic for both countries (Germany and United Kingdom) is larger than the upper limit of Pesaran et al. tables for 10% level of significance (Pesaran et al. (2001) table, page 300) for (k+1)=2 variables and for 5% level of significance for Switzerland. So, we can claim that there is a cointegrating relationship among examined series in the

Table 3: Order of optimal lags (p, q)

Number of lags	AIC	SC	HQC
Germany			
(p=1,q=0)*	−0.832	−0.760	−0.803
(p=1,q=1)	−0.821	−0.749	−0.792
United Kingdom			
(p=1,q=0)	−0.599	−0.527	−0.570
(p=1,q=1)	−0.598	−0.526	−0.569
(p=1,q=2)*	−0.602	−0.530	−0.573
(p=1,q=3)	−0.585	−0.513	−0.556
(p=2,q=0)	−0.549	−0.477	−0.520
(p=2,q=1)	−0.542	−0.470	−0.513
(p=2,q=2)	−0.547	−0.475	−0.518
(p=2,q=3)	−0.531	−0.459	−0.502
(p=3,q=0)	−0.561	−0.488	−0.532
(p=3,q=1)	−0.549	−0.477	−0.520
(p=3,q=2)	−0.556	−0.484	−0.527
(p=3,q=3)	−0.545	−0.473	−0.516
Switzerland			
(p=1,q=0)*	−0.865	−0.793	−0.836
(p=1,q=1)	−0.833	−0.761	−0.804

*Denotes the optimal lag selection, statistics in bold denote the value of the minimized AIC, SBC and HQC, AIC: Akaike Information Criterion, HQC: Hannan-Quinn criteria

Table 4: Testing independence of error terms (LM test)

Distributions	Probability
Germany	
F-stat=0.458	Prob. F (1,237)=0.498
N*R²=0.469	Prob. χ^2 (1)=0.493
United Kingdom	
F-stat=2.599	Prob. F (1,236)=0.108
N*R²=2.636	Prob. χ^2 (1)=0.104
F-stat=2.764	Prob. F (2,236)=0.098
N*R²=2.845	Prob. χ^2 (2)=0.095
F-stat=2.987	Prob. F (3,235)=0.092
N*R²=3.045	Prob. χ^2 (3)=0.087
Switzerland	
F-stat=3.868	Prob. F (1,237)=0.054
N*R²=3.903	Prob. χ^2 (1)=0.048

N: Observations

Figure 1: Dynamic stability of models

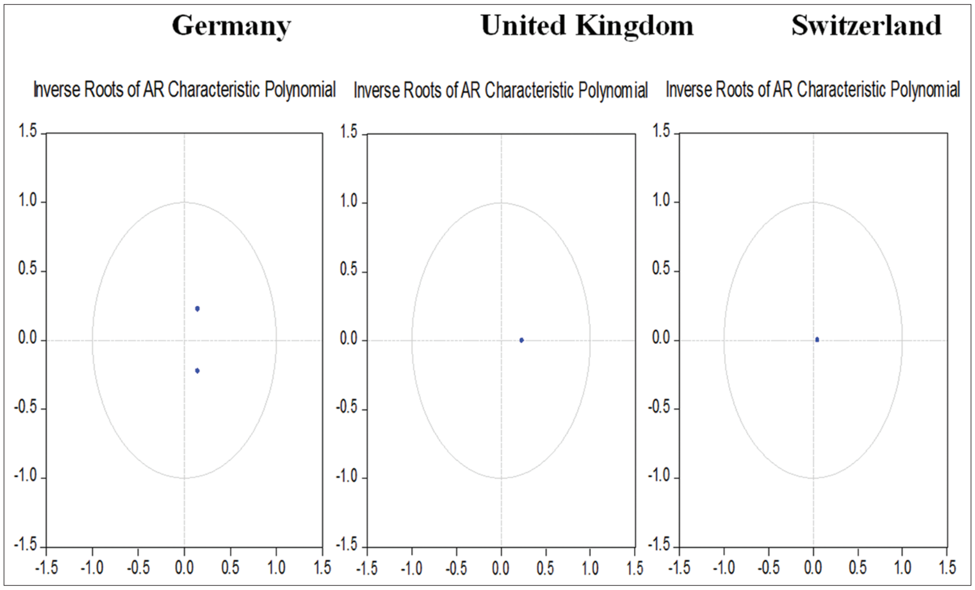
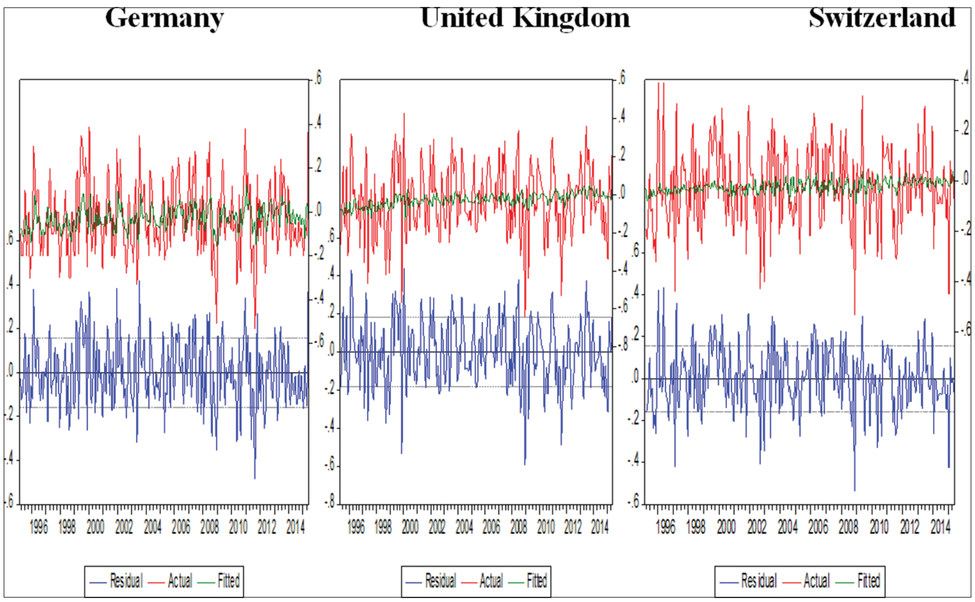


Figure 2: Actual and fitted residuals of models



three countries in 10% and 5% level of significance and Fisher's hypothesis is valid.

On the following table, the results from the estimation of the unrestricted error correction model (equation 8) are shown for the three countries.

The results on Table 6 show that both statistic and diagnostic tests are quite satisfying. Before continuing on the next step, we find the long run results from the unrestricted error correction model (equation 8).

For Germany we get:

$$-\left(\frac{INFG}{INTG}\right) = -\left(\frac{0.004}{-0.019}\right) = 0.210$$

For United Kingdom we get:

$$-\left(\frac{INFUK}{INTUK}\right) = -\left(\frac{0.0024}{-0.013}\right) = 0.184$$

For Switzerland we get:

$$-\left(\frac{INFSW}{INTSW}\right) = -\left(\frac{0.0019}{-0.016}\right) = 0.118$$

Thus, we can say that an increase in inflation by 1% will bring about increase on interest rates by 0.21% in Germany, by 0.184% in United Kingdom and by 0.118% in Switzerland.

We then estimate the long and short run relationships in series on equation (9) and (10).

The results on Table 7 show that both statistic and diagnostic tests are quite satisfying. The parameter of inflation is positive and smaller than one in the three examined countries so we can say that the weak form of Fisher's hypothesis is valid according to equation (7). We have to highlight the small value of coefficient of determination in all functions for the three countries. Generally, we can point out that the long run level of functions cannot be used to characterize the direction of monetary policy for the three countries. The restricted dynamic error correction model derived by ARDL bounds testing in a simple linear transformation, incorporates the short dynamic with a long run equilibrium. The negative and statistical significant estimation of parameters on equation (10) on error correction terms ECM_{t-1} confirm the long run relationship (Fisher's hypothesis) among the variables of the model that we study.

4.3. Testing Stability in ECM

On the following Figures 3 and 4 we examine the dynamic stability of the unrestricted error correction model of equation (10) using Brown et al. (1975) tests.

The results of the Figure 4 show that the parameters on equation (10) are stable in the three examined countries.

Table 5: Results of F bounds test (Wald test)

Test statistic	Optimal lag	Value	df	P
Germany				
F-statistic	ARDL (1,0)	4.88*	(2.238)	0.014
Chi-square		8.56	(2)	0.013
United Kingdom				
F-statistic	ARDL (1,2)	5.15*	(2.237)	0.011
Chi-square		10.562	(2)	0.015
Switzerland				
F-statistic	ARDL (1,0)	6.071**	(2.238)	0.002
Chi-square		12.142	(2)	0.002

Table CI (iii), page 300 of Pesaran et al. 2001 gives lower and upper limits for 10%, 5% and 1% levels of significance [4.04, 4.78], [4.94, 5.73] and [6.84, 7.84] respectively. *, ** and *** show significant at 1%, 5% and 10% levels respectively, ARDL: Autoregressive distributed lag

4.4. Toda –Yamamoto Causality Test

Table 8 presents the results on Toda and Yamamoto causality testing according to equations 11 and 12.

The results on Table 8 show that there is a strong one way causal relationship between interest rates and inflation with direction from interest rates to inflation for all three countries, while for Germany there is a causal relationship from inflation to interest rates on a 5% level significance.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This paper tries to examine the validity of Fisher's hypothesis for three European countries using cointegration of Pesaran et al. (2001) as well as the methodology of Granger no-causality as was developed by Toda and Yamamoto (1995). The results of the paper showed a cointegrated relationship which confirms Fisher's hypothesis and also that nominal interest rates and expected inflation move in parallel in a long run basis for the three examined countries. Paper's results also showed that for a rise of inflation by 1%, there will be an increase on interest rates in a long run basis on Germany by 0.21%, on United Kingdom by 0.184% and on Switzerland by 0.118%. Afterwards, the dynamic short run estimation of models showed that this instability is corrected every year between long and short run interest rates by 0.009% for Germany, by 0.013% for United Kingdom and by 0.015% for Switzerland. This implies that central banks on these countries can affect yield curve through short term interest rates which are affected by inflationary expectations. It is remarkable that long term interest rates determine the productive investments on a large scale.

The results of Toda and Yamamoto causality seems to suggest that nominal interest rate has a positive relationship and

Table 6: Estimation from the unrestricted error correction model (bounds test model)

Dependent variable = ΔINT_t								
Unrestricted error correction model (short run analysis)								
Germany			United Kingdom			Switzerland		
Variable	Coefficients	t-stat.	Variable	Coefficients	t-stat.	Variable	Coefficients	t-stat.
Const.	−0.001	−0.053	Const.	0.033	0.926	Const.	0.015	0.618
ΔINT_{t-1}	0.271	4.344	ΔINT_{t-1}	0.230	3.585	ΔINT_{t-1}	0.026	2.418
ΔINF_t	0.062	1.838	ΔINF_t	0.035	1.908	ΔINF_t	0.086	2.906
			ΔINF_{t-1}	0.006	1.137			
			ΔINF_{t-2}	0.041	2.294			
INT_{t-1}	−0.019	−1.996	INT_{t-1}	−0.013	−1.895	INT_{t-1}	−0.016	−1.844
INF_{t-1}	0.004	2.589	INF_{t-1}	0.0024	2.544	INF_{t-1}	0.0019	3.243
R^2	0.114		R^2	0.088		R^2	0.055	
F-stat	7.658		F-stat	3.826		F-stat	3.503	
D-W	1.943		D-W	1.939		D-W	1.993	
Diagnostic	χ^2	P	Diagnostic	χ^2	P	Diagnostic	χ^2	P
Normal	1.41 (2)	0.492	Normal	2.78 (2)	0.248	Normal	1.13 (2)	0.566
Serial	0.22 (1)	0.634	Serial	2.90 (1)	0.088	Serial	0.003 (1)	0.981
ARCH	0.00 (1)	0.974	ARCH	1.05 (1)	0.304	ARCH	0.207 (1)	0.648

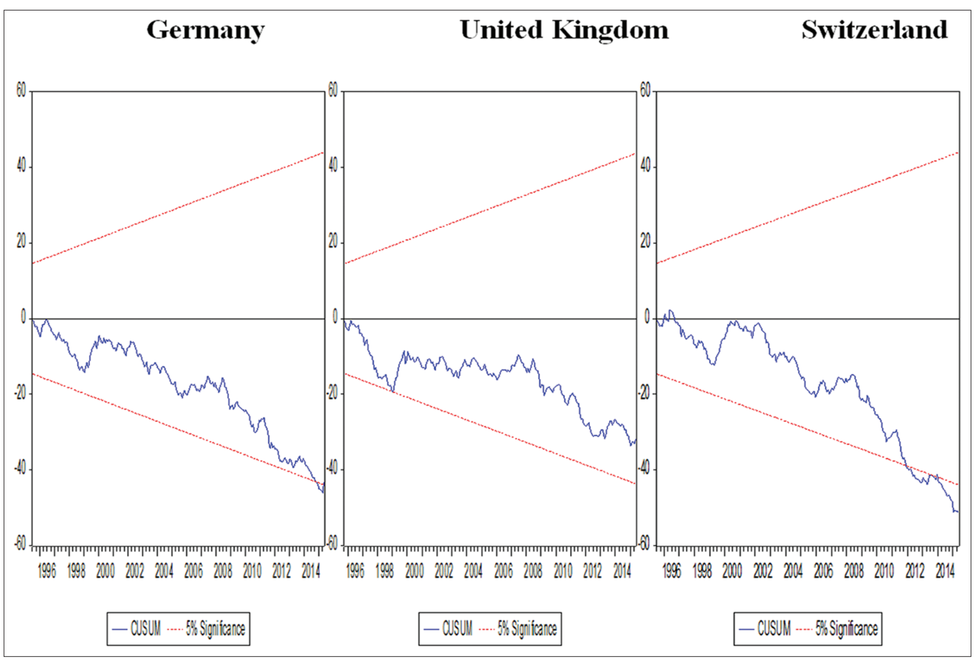
***,** and * show significant at 1%, 5% and 10% levels respectively. Δ Denotes the first difference operator, χ^2 Normal is for normality test, χ^2 Serial for LM serial correlation test, χ^2 ARCH for autoregressive conditional heteroskedasticity, ( ) is the order of diagnostic tests

Table 7: Estimation of the long and short run relationship

Dependent variable = INT_t								
Estimated long-run coefficients								
Germany			**United Kingdom**			**Switzerland**		
Variable	**Coefficients**	**t-stat.**	**Variable**	**Coefficients**	**t-stat.**	**Variable**	**Coefficients**	**t-stat.**
Const.	3.850	35.26	Const.	4.637	38.97	Const.	2.512	34.47
INF_t	0.162	1.498	INF_t	0.038	1.128	INF_t	0.589	2.811
R^2	0.341			0.298			0.331	
F-stat	0.248			0.675			7.902	
D-W	1.014			1.231			0.072	
Diagnostic	χ^2	**P**	**Diagnostic**	χ^2	**P**	**Diagnostic**	χ^2	**P**
Normal	3.35 (2)	0.185		5.75 (2)	0.056		7.33 (2)	0.025
Serial	7.14 (1)	0.017		6.09 (1)	0.018		10.1 (1)	0.004
ARCH	6.19 (1)	0.012		9.14 (1)	0.007		12.4 (1)	0.000
Dependent variable = ΔINT_t Restricted error correction model (short-run ECM)								
Germany			**United Kingdom**			**Switzerland**		
Variable	**Coefficients**	**t-stat.**	**Variable**	**Coefficients**	**t-stat.**	**Variable**	**Coefficients**	**t-stat.**
Const.	−0.019	−1.83	Const.	−0.020	−1.792	Const.	−0.020	−1.969
ΔINT_{t-1}	0.294	4.691	ΔINT_{t-1}	0.237	3.790	ΔINT_{t-1}	0.064	2.009
ΔINF_t	0.007	2.346	ΔINF_t	0.025	1.980	ΔINFt	0.025	2.127
			ΔINF_{t-1}	0.023	0.851			
			ΔINF_{t-2}	0.051	1.962			
ECM_{t-1}	−0.009	−2.395	ECM_{t-1}	−0.013	−1.889	ECM_{t-1}	−0.015	−1.657
R^2	0.189		R^2	0.287		R^2	0.218	
F-stat	7.839		F-stat	4.547		F-stat	1.518	
D-W	1.927		D-W	1.947		D-W	2.020	
Diagnostic	χ^2	**P**	**Diagnostic**	χ^2	**P**	**Diagnostic**	χ^2	**P**
Normal	1.77 (2)	0.410	Normal	2.93 (2)	0.229	Normal	1.39 (2)	0.498
Serial	1.01 (1)	0.313	Serial	1.57 (1)	0.210	Serial	6.26 (1)	0.012
ARCH	0.01 (1)	0.875	ARCH	1.13 (1)	0.287	ARCH	0.12 (1)	0.725

***, ** and * show significant at 1%, 5% and 10% levels respectively. Δ denotes the first difference operator, χ^2 Normal is for normality test, χ^2 serial for LM serial correlation test, χ^2 ARCH for autoregressive conditional heteroskedasticity, ( ) is the order of diagnostic tests

Figure 3: Plot of cumulative sum of recursive residuals



influences inflation on three examined countries considerably, whereas inflation influences interest rate only in Germany. However, we can point out that the interest rate on the three countries that we study has a strong relationship with expected inflation rates and this represents its capability to predict future inflation rates.

Figure 4: Plot of cumulative sum of squares of recursive residuals

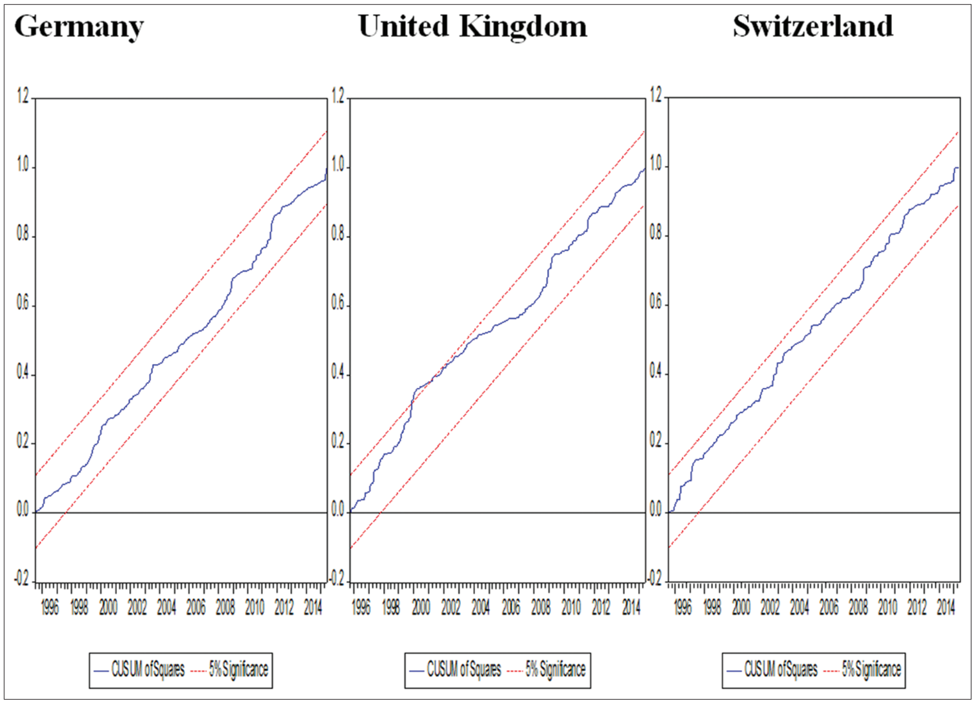


Table 8: Toda and Yamamoto no-causality test two-variate VAR model results

Excluded	Lag (k)	Lag (k+dmax)	Chi-sq	Prob.	Direction of causality
Germany					
Dependent variable: INTG					
INFG	1	1+1	6.181**	0.045	INFG→INTG
Dependent variable: INFG					
INTG	1	1+1	230.85*	0.000	INTG→INFG
United Kingdom					
Dependent variable: INTUK					
INFUK	1	1+1	1.612	0.446	INFG # INTG
Dependent variable: INFUK					
INTUK	1	1+1	110.89*	0.000	INTUK→INFUK
Switzerland					
Dependent variable: INTSW					
INFSW	1	1+1	2.783	0.248	INFSW # INTSW
Dependent variable: INFSW					
INTSW	1	1+1	236.00*	0.000	INTSW→INFSW

The (k+dmax) denotes VAR order. The lag length selection was based on LR: Sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion. *, ** and *** denotes 1% and 5%, 10% significance level, respectively. →Denotes one - way causality, # denotes not causality. EViews 9.0 was used for all computations

Finally, we have to note down that short run changes on interest rates require changes on monetary policy. However, it is important to underline that long run interest rates should support other basic factors apart from inflationary expectations.

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