Testing the Long Run Fisher Effect

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Abstract

Cointegration techniques are employed as an approach to test the Fisher hypothesis that is defined as a long-run equilibrium relationship between nominal interest rates and inflation. To that end, an extensive analysis of the integration and cointegration properties is performed for the United Kingdom, Switzerland and Germany, using monthly data of long-term rates provided by the national central banks and the IMF IFS. At the 5% significance level, evidence regarding integration and cointegration is mixed. In all cases, the findings fail to pass various robustness checks. On balance, the author concludes that there is no cointegration. The obtained results provide very little support for the long run Fisher effect. If the Fisher effect is best interpreted as a long-run equilibrium condition, these findings imply that money may not be super-neutral and that the nominal interest rate is a good indicator of market conditions.

Keywords: Fisher effect, interest rate, inflation, cointegration, stationarity

Introduction

The American mathematical economist Irvin Fisher was the first one to state the relationship between nominal interest rates, real interest rates and expected inflation.[1] His Theory of Interest (1930) was dedicated to the memory of John Rae and Eugene von Böhm-Bawerk, who laid the foundation upon Fisher built. The Fisher hypothesis is about the basic idea that people demand a compensation for the loss in purchasing power associated with inflation. That is, people demand an inflationary premium. Therefore, the nominal interest rate consists out of the expected real interest rate and an inflationary premium. Or put it another way, the expected real interest rate equals the nominal interest rate minus the expected inflation.

The expected real interest rates and expected inflation are not observed in practice. Therefore, we are always dealing with a joint test of the Fisher hypothesis and a hypothesis about the way inflation expectations are formed. The literature has suggested several proxies[2], including surveys, market prices, ARMA forecasts and regressions with the ex post real rate[3]. Kozicki and Tinsley (1998) show that the empirical performance of economic theories can be affected by the way expectations are modeled. This author follows modern research by incorporating rational expectations into the Fisher hypothesis[4].

The strict form of the Fisher hypothesis states that the nominal interest rates move one-to-one with expected inflation. Fahmy and Kandil (2002) argue that, according to the Fisher effect, the strength of this relationship should increase with

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[1] Fisher also was the first one to distinguish between nominal interest rates and real interest rates.
[2] For a discussion the author suggests Smant (2011) and Cooray (2002).
[3] It is impossible for us to distinguish between a time varying risk premium and the real interest rate. Proxies derived from ex post rates may therefore be polluted.
[4] The assumption of rational expectations will be discussed in more detail in the methodology section.

maturity.[5] That is, investors demand a higher inflationary premium for longer maturities, because of interest rate risk increasing with maturity.[6] This risk rises namely with inflation as traders anticipate a future rise in the interest rate (Fahmy and Kandil, 2002).

In this paper it is assumed that the real interest rate is constant, as it should remain unaffected by inflation. Moreover, non-stationarity of the real interest rate is a very low probability event (Cochrane, 1991) and inconsistent with conventional growth theory (Johnson, 2005) and the CCAPM (Rose, 1988). Of course, a constant real interest rate is a stronger assumption than a stationary real interest rate. Peng (1995) notes that the assumption of a constant real interest rate has been criticized on the basis that the real interest rate responds to changes in economic factors. Mehra (1998) relaxes the assumption regarding the constant real interest rate by controlling for the influences of variables that capture movements in the real interest rate. However, Peng (1995) argues that this approach is problematic, because the mixture of short run and long run movements makes it difficult to interpret the results. It has therefore been argued that the Fisher effect is best interpreted as a long run relationship (Summer, 1983). The methodology of Jorion and Mishkin (1991) relaxes the assumption of a constant real interest rate by using a changes specification. The assumption is then that the change in the real interest rate is constant. The author finds this a more plausible assumption, because first differences are less volatile that the levels of the real interest rate. Alternatively, Gerlach (1997) uses a changes specification where the constant consists out of the difference between the means of the term or risk premiums; he puts the difference of the real interest rate in the error term. Fahmy and Kandil (2002) even make the assumption that the real interest rate is

[5] This is consistent with empirical findings. See for example Jorion and Mishkin (1991), Yuhn (1995), Gerlach (1997), Schich (1999) and Fahmy and Kandil (2002).
[6] Santoni (1984) suggests a positive correlation between interest rate risk and maturity.

zero by excluding it from the cointegration test specification. By not including an intercept in the cointegrating equation, they artificially obtain a higher slope coefficient.

The relationship referred to as the Fisher effect is still the basic understanding in financial economics. However, there is little empirical support for the validity of this relationship in countries other than the US (Crowder, 1997). In this paper cointegration analysis is performed in order to test the long-run Fisher effect. For theory it is interesting to investigate whether a general relationship holds. The countries under consideration are the United Kingdom, Switzerland and Germany.[7] The central question of this paper is thus whether the long run Fisher effect has empirical validity.

This paper contributes to the research of the Fisher effect in various ways. Of interest are the following issues. The author investigates whether the Fisher effect is a common future of different economic regimes. Furthermore, this paper uses varying maturities at the longer end of the maturity spectrum. This focus on varying maturities is in particular interesting in the light of the finding in the literature that the strength of the relationship increases with maturity.[8] Moreover, Smant (2011) mentions two reasons to use long-term rates rather than short-term rates. First, short term rates are likely to be directed by monetary policy, whereas the relationship between monetary policy and longer-term interest rates is weak. Second, important financial decisions tend to be medium-term to long-term and should therefore be linked to interest rates of corresponding maturity. For the rest, the use of monthly data may avoid the

[7] This selection is based on diversity and availability of data. Interest rates and inflation have historically been more stable in Germany than in the United Kingdom. The different inflation history inter alia may have consequences for the Fisher effect. Of course, the three countries differ from each other in a lot of ways. The availability of data is in particular important, because cointegration analysis requires a long time span.

[8] See for example Jorion and Mishkin (1991), Yuhn (1995), Gerlach (1997), Schich (1999) and Fahmy and Kandil (2002).

aggregation bias problem that arises when using annual data (Rossana and Seater, 1995). Lastly, comprehensive robustness checks are performed when analyzing the integration and cointegration properties. Unit root tests are accompanied by stationarity tests[9]. To the author's best knowledge, the Gregory-Hansen test and the Johansen technique so far have not been applied complementary to each other. Within the Johansen framework, additional restrictions are imposed to make statistical inference more robust in the presence of near integrated variables.[10] The analysis has been improved by the use of graphs.

The structure of this paper is as follows. First, the author discusses some findings of similar previous research. Second, we deal with the concepts of integration and cointegration. Third, data and methodology are discussed. After that, empirical results of the extensive cointegration analysis are provided and discussed. Finally, the author draws a conclusion.

Literature Review

As noted, there is little empirical support for the existence of a long-run Fisher effect. In the literature, some results of cointegration tests for the countries under consideration are as follows.[11]

Beyer, Haug and Dewald (2009) use short-term interest rates on a quarterly basis and only find a cointegrating relationship for Germany. Using a recently developed test by Carrion-i-Sylvestre and Sans (2006), the authors account for structural breaks within the Johansen framework and then also find cointegration in the United Kingdom and Switzerland. Only in the case of Germany, they fail to reject the restriction that inflation and interest rates move one-for-one.

[9] This is known as confirmatory data analysis.
[10] As suggested by Hjalmarsson and Österholm (2007). This issue is discussed in more detail in the empirical results section under ''robustness checks''.
[11] For a more elaborate general literature review the author recommends Cooray (2002).

Granville and Mallick (2004) test the Fisher effect for the United Kingdom over a horizon from 1900 to 2000, using annual observations of three-month rates. Despite mixed evidence of the integration properties, using the Johansen technique Granville and Mallick find evidence that the short-term nominal interest rate and the inflation rate cointegrate with a slope of 1.355.

Engsted (1995) applies the Johansen technique using quarterly data of long-term interest rates. When analyzing the integration properties he finds that the nominal interest rate for Switzerland, and perhaps Germany, is stationary. However, the additional stationarity tests within the Johansen framework suggest that the variables under investigation are non-stationary. Both the maximum likelihood test and the trace test suggest the presence of a cointegrating relationship for Germany, Switzerland and the United Kingdom. Following Sheller and Siegel (1977) he sets the slope coefficient equal to 0.97 when imposing the restriction on the VECM.[12] The restriction is only rejected for the United Kingdom.

Peng (1995) uses short-term rates at quarterly frequencies and finds that the German inflation and nominal interest rates are stationary. Therefore, Peng does not include Germany in the cointegration analysis. Using the residual-based Engle-Granger Approach she detects the presence of cointegration for United Kingdom. Johansen's maximum likelihood test confirms the existence of a cointegrating relation. Peng obtains an estimate of the unrestricted slope coefficient equal to 0.94.

Lastly. Yuhn (1995) uses quarterly short-term and long-term rate from 1973 to 1993. He finds that the long-term nominal interest rate of the United Kingdom is stationary. Based on results obtained from the Johansen procedure Yuhn concludes

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[12] Engsted (1995) notes that this slope coefficient corresponds to a constant expected real interest rate of 3% per annum.

that the long-run Fisher effect is pronounced in Germany and that there is little evidence for the United Kingdom.

Integration and Cointegration

This paper employs the cointegration approach in order to test the long run Fisher effect. Therefore the author will briefly introduce the concepts of stationarity and cointegration. The discussion is based on Brooks (2010), Hendry and Juselius (1999) and Hendry and Juselius (2000).

Stationarity

A variable that is stationary has a constant mean, constant variance and constant autocovariances. The stationarity properties of a variable are important for empirical modeling, because they influence the behavior of variables.

A non-stationary variable is one that does not fit the definition of a stationary variable. We can distinguish between deterministic non-stationarity and stochastic non-stationarity. Here only the latter is discussed. The stochastic non-stationary variable is also known as a unit root process. The use of non-stationary variables may cause spurious regressions. To illustrate the relevance in the literature, Miskin (1992) writes:

> In this section we will reexamine this methodology for testing the Fisher effect and show that it does not provide reliable evidence on the existence of the Fisher effect. The problem with this methodology is that it is subject to the spurious regression phenomenon described by Granger and Newbold (1974) and Phillips (1986) because both the right- and left-hand-side variables in the regression equation above can be characterized as having unit roots. (p. 196)

The spurious regression problem also arises when variables are stationary but near integrated (Hjalmarson and Österholm, 2007). According to Hjalmarsson and

Österholm (2007) there is little a priori reason to believe that the inflation rates and nominal interest rates have an exact unit root, rather than a close unit root. Hendry and Juselius (1999) argue that in the case of a close unit root it is often a good idea to act as if there is a unit root, to obtain robust statistical inference.

Order of integration.

Stationarity of a non-stationary variable x can be achieved after differencing d times. It is then said that the non-stationary variable is integrated of order d, or more formally $x \sim I(d)$. For example, if the first difference of a non-stationary variable is stationary, the variable is integrated of order 1 or $I(1)$. Similarly, a variable that is stationary without differencing is said to be integrated of order 0, denoted by $I(0)$.

The order of integration has major implications for economic theory and policy[13]. The order of integration is also interesting from an empirical point of view, because it is very important when deciding on which econometric technique to apply. For example, the standard Johansen procedure that is applied in this paper allows only for $I(0)$ and $I(1)$ variables.

Theoretical considerations.

As we will see in the next section, there are a lot of weaknesses associated with unit root tests. Therefore, analysis requires some economic reasoning. It is wise to take theoretical considerations into account before drawing conclusions about the stationarity properties of variables. Hendry and Julius (1999) illustrate how a unit-root in the long-term interest rate can arise as a consequence of plausible economic behavior:

> If changes to long-term interest rates (R_l) were predictable, and $R_l > R_s$ (the short term rate) – as usually holds, to compensate lenders for tying up their

[13] See e.g. Libanio (2005)

> money – one could create a money machine. Just predict the forthcoming change in R_l, and borrow at R_S to buy bonds if you expect a fall in R_l (a rise in bond prices) or sell short if R_l is likely to rise. Such a scenario of boundless profit at low risk seems unlikely. (p.7)

In that case, the non-stationarity of the nominal interest rate will be transmitted to related variables such as the inflation rate. That is, the inflation rate will inherit the non-stationarity, because the variables are related according to economic theory.
On the other hand, a unit root implies that these variables can take on values from plus to minus infinity. This is not very plausible.

Basher and Westerlund (2006) control for structural breaks and cross-sectional correlation[14] and find that inflation is stationary. The empirical evidence is extremely mixed.

Cointegration

Some linear combination may (but need not) be *I*(0) even if the variables individually are *I*(1), i.e. the variables may be cointegrated or *CI*(1,1). Cointegration means that non-stationary variables cannot move boundless from each other, since the variables are bound by some relationship in the long run.

A long run relationship between variables should be suggested by financial theory. It has been argued that the Fisher effect is best interpreted as an equilibrium condition (Summer, 1983). That means that there can be deviations from this equilibrium relation in the short run, but in the long run nominal interest rates should move one-to-one with expected inflation. Johnson (2005) argues that cointegration

[14] Basher and Westerlund (2006) argue that inflation usually exhibits strong comevement across countries.

does not imply the Fisher hypothesis, but the Fisher hypothesis does imply cointegration if the variables are non-stationary.[15]

As an illustration, we have the following regression model:

$$i = \alpha + \beta\pi + \varepsilon$$

, where the nominal interest rate *i* and the inflation rate π are found to be *I*(1). The constant α represents the real interest rate. When taking the residual ε as the left hand side variable, we obtain:

$$\varepsilon = i - \alpha - \beta\pi$$

If we find that the residual ε is I(0), the linear combination of I(1) variables will be stationary. In that case, the nominal interest rate *i* and the inflation rate π are cointegrated.[16] If such a long-run relationship exists, it is inadvisable to induce stationarity by differencing. The regression will have no long-run solution.

A good alternative is the error correction model (ECM) of the form:

$$\Delta i_t = \beta_0 + \beta_1 \Delta\pi_t + \beta_2 \left(i_{t-1} - \alpha - \gamma\pi_{t-1}\right) + \epsilon_t$$

where β_0 is the constant, $\beta_1$describes the short-term relationship between Δi_t and $\Delta\pi_t$, β_2 is the speed of adjustment back to equilibrium, the stationary linear combination $i_{t-1} - \alpha - \gamma\pi_{t-1}$ is the error correction term with a lag, γ describes the long-run relationship between i_t and π_t.

As cited in Hendry and Juselius (1999), Engle and Granger (1987) proved that error correction models and cointegration are the same thing: cointegration entails a feedback involving the lagged levels of the variables and a lagged feedback entails cointegration. (p. 12)

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[15] That is, the presence of cointegration is not enough for the Fisher effect to hold. However, Mishkin (1992) did define the long run Fisher effect as the presence of cointegration between the rates under investigation.

[16] In fact, this is the residual based approach of detecting cointegration. The Gregory-Hansen test discussed in the empirical results section is based on this approach.

You may be interested in a more elaborate discussion of the concepts of stationarity and cointegration. In that case the author strongly recommends Hendry and Juselius (1999) and Hendry and Juselius (2000).

Data

The author makes use of long-term nominal interest rates provided by the national central banks of the United Kingdom, Switzerland and Germany. The nominal interest rates are end-of-the-month observations of the zero coupon yield on long-term government bonds. The rates under investigation have a (residual) time to maturity varying from 1 to 5 years.

An exception is Germany. For Germany we use estimates of spot rates based on the method by Svensson (1994) that has replaced the traditional method since 1997. The new method is more flexible as it is capable of capturing more complex shapes of the term structure of nominal interest rates (Schich, 1999). For a discussion you may want to read Deutsche Bundesbank (1997) or Schich (1999).

All rates are continuously compounded.[17] The inflation rate is the consumer price index of the IMF International Financial Service. The realized m-year inflation rate π_t^m is computed as $\frac{\ln(CPI_{t+12m}/CPI_t)}{m} x100\%$, where CPI_t is the consumer price index in month t and m denotes the years to maturity.

Appendix A provides descriptive statistics. The descriptive statistics do not indicate any errors in variables. Note that the author may refer to the United Kingdom as UK, Switzerland as CH and Germany as D.

[17] This enhances comparability between papers, makes series less heteroskedastic and allows for additional interpretations.

Methodology

Starting point is a Fisher decomposition of the nominal interest rate:

(1) $i_t^m = r_t^m + E_t[\pi_t^m]$

where, i_t^m is the m-year nominal interest rate; r_t^m is the m-year ex ante real interest rate; E_t is the expectations operator conditional on information available at time t; π_t^m is the inflation rate realized over the next m years.

Assuming rational expectation using the perfect-forecast-with-error model, the realized m-year inflation rate can be decomposed into an expected component and a forecast error:

(2) $\pi_t^m = E_t[\pi_t^m] + \epsilon_t$

Incorporating rational expectations into equation 1, we obtain the following equation in estimable form:

(3) $i_t^m = \alpha^m + \beta^m \pi_t^m + \varepsilon_t$

where, α^m describes the m-year real interest rate and β^m is the slope coefficient that should equal unity. The cointegration equation has the form of equation (3).

The Johansen technique is the central cointegration test in this paper. First, a VAR with k lags is set up:

(4) $y_t^m = \beta_0 y_{t-1}^m + \cdots + \beta_k y_{t-k}^m + \varepsilon_t,$

where y_t^m is a vector of the nominal interest rate and inflation rate. The VAR in equation (4) is turned into a vector error correction model (VECM) in order to apply the Johansen technique:

(5) $\Delta y_t^m = \alpha^m + \Pi y_{t-k}^m + \Gamma_1 \Delta\, y_{t-1}^m + \cdots + \Gamma_{k-1} \Delta\, y_{t-(k-1)}^m + \varepsilon_t$

, where coefficient matrices $\Pi = (\Sigma_{i=1}^k \beta_i)$ - I_g and $\Gamma_i = \Sigma_{j=1}^i \beta_j - I_g$, α^m is a vector of constants, ε_t is a vector of error terms. The cointegration test is based on the rank of Π.

Note that no constant is included in the VAR, whereas the VECM does contain a constant. This specification is consistent with the Fisher effect, as it included a constant and no deterministic trends. For the sake of clarity, additional (econometric) issues will be discussed in the empirical results section.

Empirical Results

The cointegration analysis involves several steps. First, stationarity properties of the variables under investigation are determined. Second, two approaches are used to test for the presence of a cointegrating relation. Third, imposed restrictions on the VECM are tested using Johansen's likelihood ratio test.

Determining the Stationarity Properties

Visual inspection of the graphs of the time series reveals that the level data may not come from a stationary process.[18] Appendix B contains a complete overview of graphs for the United Kingdom, Germany and Switzerland.

Unit root tests are accompanied by stationarity tests to formally judge whether the variables are stationary or not. The results of the Augmented Dickey Fuller unit root test (hereafter referred to as the ADF test) are compared to the results of the Kwiatkowski–Phillips–Schmidt–Shin stationarity test (hereafter KPSS test) to see if the same conclusion is obtained.

The null hypothesis of the ADF test is that the variable contains a unit root, i.e. the variable is non-stationary. The null hypothesis of the KPSS test is that the variable is stationary. The lag length is determined optimally using information

[18] As noted in the data section, all variables are in logs. This transformation produces more homogeneous series. If the log has a unit root, the original must be explosive (Hendry and Juselius, 2000).

criteria.[19] Table 1 shows the results of these tests on the level and first differences of the variables under investigation.

Table 1

Results of the ADF unit root test and the KPSS stationarity test

			Level				First difference	
			trend and intercept		intercept		intercept	
Country	m		ADF t-statistic	KPSS LM-statistic	ADF t-statistic	KPSS LM-statistic	ADF t-statistic	KPSS LM-statistic
United Kingdom (UK)	1	i	-2.2454	0.3917***	-1.1258	1.7422***	-20.6058***	0.0788
		π	-2.9121	0.1966**	-1.7988	1.7059***	-6.8487***	0.0413
	2	i	-2.5580	0.4100***	-1.0364	1.9171***	-20.1289***	0.1122
		π	-2,3349	0.2258***	-1.4662	1.8035***	-9.3933***	0.0757
	3	i	-3.0661	0.4114***	-1.2388	2.0178***	-19.7574***	0.1113
		π	-3.1248	0.2945***	-1.7864	1.9067***	-4.4222***	0.1020
	4	i	-3.1516*	0.4085***	-1.2052	2.0770***	-19.7890***	0.1158
		π	-2.2222	0.4069***	-1.4800	1.9947***	-4.4497***	0.1503
	5	i	-2.8534	0.4035***	-0.9492	2.1167***	-20.1350***	0.1245
		π	-0.9003	0.4787***	-1.9483	2.1476***	-5.4164***	0.2587
Switzerland (CH)	2	i	-2.7278	0.1571**	-0.9241	1.3737***	-13.9760***	0.1226
		π	-0.9905	0.3611***	1.3667	1.1021***	-14.1936***	0.1869
	3	i	-2.8059	0.1432*	-0.9604	1.4297***	-13.8193***	0.1173
		π	-2.3476	0.3889***	-2.8811**	1.0657***	-4.0189***	0.3764*
	4	i	-2.8540	0.1361*	-0.9856	1.4653***	-13.4395***	0.1131
		π	-2.0037	0.4161***	-3.1531**	1.1039***	-3.3966**	0.8788***
	5	i	-2.8849	0.1311*	-0.9890	1.4917***	-13.2289***	0.1089
		π	-2.6909	0.4052***	-3.9043***	1.0766***	-3.3381**	1.0813*
Germany (D)	1	i	-2.4692	0.1118	-1.7505	1.3922***	-18.5773***	0.0688
		π	-2.5811	0.1304*	-2.4233	1.1872***	-7.8073***	0.0555
	2	i	-2.5120	0.1201*	-1.3853	1.6323***	-16.8754***	0.0889***
		π	-2.2368	0.1346*	-2.2080	1.1524***	-11.4753***	0.1212
	3	i	-2.6144	0.1284	-1.2947	1.8059***	-16.9757***	0.0815
		π	-2.1182	0.1349*	-2.2107	1.1704***	-8.1307***	0.1659
	4	i	-2.7341	0.1362*	-1.2562	1.9192***	-16.8423***	0.0752
		π	-1.8638	0.1373*	-2.0500	1.2205***	-7.5790***	0.1597
	5	i	-2.8164	0.1427*	-1.2211	1.9913***	-16.9344***	0.0707
		π	-1.6765	0.1459*	-1.7563	1.2869***	-7.2074***	0.1675

Note. The *m* column indicates the maturity in years. The nominal interest rate is denoted by *i*. The inflation rate is denoted by π. The ADF test has $H_0: y_m \sim I(1)$. The KPSS test has $H_0: y_m \sim I(0)$. $*p < .10$. $**p < .05$. $***p < .01$

In the more general case the specification includes an intercept and time trend. At the 5% significance level the results of the ADF test indicate that for all countries and maturities both the nominal interest rate and inflation rate is non-stationary in levels.

[19] If the errors suffer from autocorrelation too few lags will not solve the problem, whereas too many lags reduce the power of the test. An ADF test with a lag length of zero is equivalent to the ordinary Dickey-Fuller test.

However, the KPSS test fails to reject the null hypothesis for the 3-year, 4-year and 5-year Suisse interest rate. Furthermore, the KPSS test results indicate that in the case of Germany both the interest rates and inflation rates are stationary for all maturities. These outcomes imply conflicting results for Germany and Switzerland. For the United Kingdom, the results of both tests suggest that the interest rates and inflation rates are non-stationary. However, these findings are not robust for the specification.

When using the intercept specification, the ADF test only rejects a unit root in the CH 3-year inflation rate, the CH 4-year inflation rate and the CH 5-year inflation rate. However, the KPSS test rejects stationarity in all cases. This implies conflicting results in the case of Switzerland. For Germany and the United Kingdom, the results strongly indicate that the variables under investigation are non-stationary.

In all cases the ADF test results suggest that the first difference of the variables is stationary, suggesting that the variables are integrated of order 1, that is $I(1)$. In most cases the same conclusion is obtained by using the KPSS test. However, the KPSS test does strongly reject the stationarity of the first difference of the CH 4-year inflation rate and the D 2-year interest rate.

Unit root tests such as the ADF test are known to have low power in finite samples and when the root is close to the non-stationary boundary. Another weakness of conventional unit root tests is that they are very sensitive to structural changes (Perron, 1989). When ignoring the structural break, the power to correctly reject the null hypothesis decreases. Structural breaks may be confused as support for non-stationarity. For long time spans, inflation rates and nominal interest rates are likely to be subject to structural changes, such as regime shifts.

Unit root test with one structural break.

The Zivot and Andrews (1992) procedure is used to test for unit roots with a structural break. The null hypothesis of the Zivot and Andrews Unit Root test (hereafter referred to as ZAURoot test) is a unit root with a structural break. The test endogenously identifies the most probable break point. The level shift specification allows for a structural change in the level. The regime shift specification allows for a structural change in both the level and the slope of the trend.

According to Perron, most economic time series can be modeled using either the level shift or the regime shift specification. Based on the observations of Sen (2003) it has been argued that the regime shift specification is, in terms of power, superior to the level shift specification. Results of the ZAURoot test are presented in Table 2.

In the presence of a regime shift, the ZAURoot test rejects a unit root in the UK 4-year interest rate, UK 5-year interest rate, CH 4-year inflation rate and the CH 5-year inflation rate. All German variables under investigation and the remaining variables for Switzerland and the United Kingdom are non-stationary. In the presence of a level shift, the ZAURoot test rejects the non-stationarity of the UK 3-year inflation rate. Again most results indicate that the variables under investigation are non-stationary. This finding is robust for the specification used.

For the UK the most probable structural breaks occur around the 1980's, starting in 1977 and ending in 1981.[20] Interestingly, the same holds for Germany, which suggests that the breakpoints are likely to be associated with the energy crisis of the 1970's. The second oil crisis began in 1979 and the oil glut was in 1980. These

[20] The discussion of the chosen break points may have a strong flavor of story telling. However, the aim of this discussion is to associate the breakpoints with certain events rather than to provide genuine explanations. The author does make a first step in the construction of such an explanation. Future research may be conducted in this direction.

events inevitably resulted in the indicated shifts as they had an effect on prices, production and policy. The most probable breakpoints for Switzerland are identified in the early 1990's, and not during the years of the energy crisis. This may be associated with the independent and neutral status of the country. The major event in the beginning of the 1990's is the deep recession that lasted 3 years.

Table 2

Results of the Zivot-Andrews Unit Root test

Country	m		Regime shift		Level shift	
			ZAURoot t- statistic	Chosen break point	ZAURoot t- statistic	Chosen break point
United Kingdom (UK)	1	i	-4.2090	1978M03	-3.9561	1977M12
		π	-5.0033*	1979M04	-4.6951*	1980M12
	2	i	-4.5780	1981M12	-4.0449	1977M10
		π	-4.2656	1979M04	-4.3380	1979M04
	3	i	-4.9888*	1981M12	-4.1127	1977M08
		π	-4.8038	1979M05	-5.0545**	1979M05
	4	i	-5.1368**	1981M12	-4.0995	1977M08
		π	-4.5268	1978M11	-4.3637	1978M11
	5	i	-5.0893**	1981M12	-4.0381	1977M12
		π	-3.7695	1978M11	-2.9466	1976M07
Switzerland (CH)	2	i	-4.3049	1992M08	-4.6207*	1992M08
		π	-4.5101	1991M11	-3.8094	1991M11
	3	i	-4.2704	1992M08	-4.1781	1992M09
		π	-4.6744	1992M10	-2.9955	1991M05
	4	i	-4.3286	1992M08	4.1791	1992M09
		π	-5.4994**	1992M11	-2.1150	1991M05
	5	i	-4.3631	1992M08	-4.0179	1992M09
		π	-5.7741***	1992M11	-3.0947	1991M01
Germany (D)	1	i	-4.1372	1978M12	-3.5207	1978M12
		π	-3.6067	1981M07	-3.6681	1981M07
	2	i	-3.7947	1978M07	-3.4713	1979M01
		π	-3.2873	1980M11	-3.2109	1980M11
	3	i	-3.9550	1978M07	-3.5530	1979M02
		π	-3.3304	1980M10	-3.1190	1980M10
	4	i	-3.9562	1978M06	-3.4428	1979M02
		π	-2.9575	1979M10	-2.8392	1980M11
	5	i	-4.0476	1978M06	-3.4970	1979M02
		π	-2.8411	1978M10	-2.6747	1980M02

Note. The *m* column indicates the maturity in years. The nominal interest rate is denoted by *i*. The inflation rate is denoted by π. The ZAURoot test has $H_0 : y_m \sim I(1)$ in the presence of one structural break. The regime shift model allows for changes in both the level and the slope of the trend. The level shift model allows for a structural break in the intercept. Maximum lag length is 4. *$p < .10$. **$p < .05$. ***$p < .01$

Cointegration Analysis

On balance the test results suggest that the variables under investigation are non-stationary, i.e. *I*(1). However, the variables cannot move too far from each other. The Fisher effect implies that the variables should be cointegrated. That is, some linear combination may (but need not) be *I*(0) even if the variables individually are *I*(1). In this section two different approaches are used to investigate whether such a long-run relationship exists.

The Gregory and Hansen test

Gregory et al. (1996) illustrated the problems with standard cointegration tests in the presence of structural breaks. In the presence of a structural break the power of conventional residual-based tests decreases. The break introduces unit root behavior in the cointegrating relation.

Gregory and Hansen (1996) proposed an ADF-, Z_a- and Z_t-type residual-based test that with a null hypothesis of no cointegration versus the alternative hypothesis that there is cointegration in the presence of a structural break. The test is capable of detecting at most 1 cointegrating relationship. This does not present a problem in the case of 2 variables.

For the sake of simplicity this paper is only concerned with the most general case of a structural break, which is the regime shift. Other cases require more careful analysis. The regime shift model allows for a single change in both the level and the slope of the coefficient.

The results of the Gregory-Hansen test are likely to depend on the choice of the exogenous variable that in this case could be either inflation or the nominal interest rate. In this paper both alternatives are tested.[21]

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[21] However, it may be that the causality goes in both directions.

Table 3 presents the results of the Gregory-Hansen test for cointegration in the presence of a regime shift. The null hypothesis of the Gregory-Hansen test is no cointegration. The alternative hypothesis is cointegration in the presence of a structural break.

If the nominal interest rate is the dependent variable, that is inflation is exogenous, the test results strongly suggest that there is no cointegration. If inflation is the dependent variable, only in the case of the GB 1-year rates there is enough evidence against the null hypothesis of no cointegration. However, the existence of a cointegrating relation is not a sufficient condition for the Fisher effect to hold (Johnson, 2005).

By identifying break dates, the Gregory and Hansen test facilitates the analysis of whether a change in the cointegrating relationship is consistent with the Fisher hypothesis. If the Fisher effect holds, not all shocks should cause a change in the cointegrating relation.[22]

The source of the breakpoint is in particular interesting in the case of the GB 1-year rates.[23] In this case the Gregory-Hansen test indicates that there is cointegration in the presence of a regime shift that occurs during the energy crisis, to be precise in 1979. This structural break is therefore likely to be associated with a supply shock. This would be consistent with the Fisher effect.[24]

[22] According to Beyer, Haug en Dewald (2009) when the strong version of the Fisher holds, monetary shocks should not cause changes in the cointegrating relation, because inflation will not affect real interest rates.
[23] Previously, the ZAURoot test identified different break points. Differences may arise as a consequence of the specification used and the number of lags.
[24] As noted before, future research should be done in this direction. It is interesting to make pre- and post-break subsamples as in Beyer, Haug en Dewald (2009). However, cointegration analysis requires a long time span.

Table 3

Results of the Gregory-Hansen cointegration test with regime shifts

			i is the dependent variable			π is the dependent variable		
Country	Maturity in years		Test statistic	Break date	Lag length	Test statistic	Break date	Lag length
United Kingdom (UK)	1	ADF	-3.2839	1979M01	2	-5.5288***	1979M12	2
		Z_α^*	-30.4532	1980M01		-53.1591**	1979M09	
		Z_t^*	-4.2964	1979M08		-5.3824**	1979M09	
	2	ADF	-3.7647	1992M05	1	-4.1262	1979M01	1
		Z_α^*	-29.3392	1979M02		-31.6050	1979M09	
		Z_t^*	-4.2657	1980M01		-4.2572	1979M09	
	3	ADF	-3.9831	1992M05	1	-3.8949	1979M01	1
		Z_α^*	-28.9711	1992M05		-25.0025	1979M01	
		Z_t^*	-3.9329	1992M05		-3.7933	1979M01	
	4	ADF	-3.9769	1992M05	1	-3.8243	1979M06	0
		Z_α^*	-27.5853	1992M05		-26.6134	1979M01	
		Z_t^*	-3.8138	1992M05		-3.9732	1979M01	
	5	ADF	-3.8869	1992M05	1	-3.7556	1979M02	0
		Z_α^*	-26.6050	1992M05		-27.7000	1979M02	
		Z_t^*	-3.7474	1992M05		-3.9347	1979M02	
Switzerland (CH)	2	ADF	-3.2064	1995M12	1	-4.1590	1991M11	0
		Z_α^*	-17.9721	1994M06		-34.9183	1991M07	
		Z_t^*	-3.4036	1993M04		-4.3672	1991M07	
	3	ADF	-3.7191	1994M08	1	-4.2402	1991M05	0
		Z_α^*	-22.6289	1994M08		-33.0903	1991M06	
		Z_t^*	-3.6417	1994M08		-4.2729	1991M06	
	4	ADF	-4.1255	1994M03	2	-4.2095	1991M05	0
		Z_α^*	-29.2695	1993M04		-33.7331	1991M06	
		Z_t^*	-4.0249	1993M04		-4.3129	1991M06	
	5	ADF	-3.9658	1993M04	1	-4.8032*	1991M05	0
		Z_α^*	-30.8149	1992M12		-42.5220*	1991M06	
		Z_t^*	-4.1795	1992M12		-4.8332*	1991M06	
Germany (D)	1	ADF	-4.0236	1980M07	1	-4.8471*	1981M07	2
		Z_α^*	-32.1336	1980M07		-40.3942	1980M07	
		Z_t^*	-4.1210	1980M07		-4.6077*	1980M07	
	2	ADF	-3.6846	1996M04	2	-3.6169	1980M06	2
		Z_α^*	-24.6549	1996M03		-22.7557	1980M07	
		Z_t^*	-3.6658	1996M03		-3.6272	1980M07	
	3	ADF	-3.3941	1994M04	2	-2.7216	1995M02	0
		Z_α^*	-20.1264	1994M10		-13.1003	1980M06	
		Z_t^*	-3.2333	1994M10		-2.8793	2001M01	
	4	ADF	-2.9864	1994M03	1	-2.3620	1984M09	3
		Z_α^*	-19.2472	1994M03		-8.9946	1978M07	
		Z_t^*	-3.1563	1994M03		-2.3628	2000M03	
	5	ADF	-2.9870	1993M04	1	-2.2277	1983M02	1
		Z_α^*	-18.1834	1993M05		-9.5328	1978M07	
		Z_t^*	-3.1220	1982M06		-2.2272	1980M08	

Note. The *m* column indicates the maturity in years. The nominal interest rate is denoted by *i*. π is the inflation rate. The Gregory-Hansen test has H_0 : no cointegration versus H_a: cointegration in the presence of a structural break. The regime shift model allows for changes in both the level and the slope of the coefficient. Maximum lag length is 4 (SIC). *$p < .10$. **$p < .05$. ***$p < .01$. The critical values for the ADF, Z_t^* statistic are -4.68*, -4.95**, -5.47***. Critical values for the Z_α^* statistic are -41.85*, -47.04** and -57.17***.

Overall, there is very little empirical support for cointegration between the variables under investigation. The finding of no cointegration is robust to different countries, maturities and the specification used.

However, there are several weaknesses associated with the test.[25] Gregory and Hansen (1996) believe that empirical investigations will be best served by using complementary statistical tests. In the next section, cointegrating systems are tested and estimated using the far superior Johansen (1988) procedure.[26]

The Johansen procedure

Johansen's maximum eigenvalue test and trace test are used to test whether inflation and nominal interest rates cointegrate. The tests are calculated via the number of eigenvalues that are significantly different from zero. The trace test has H_0: ≤ r versus H_a: >r ; the hypotheses for the maximum likelihood test are H_0: r and H_a: r+1, where the rank *r* is the number of cointegrating vectors. The Johansen technique also gives an unrestricted estimate of the slope coefficient.

In this case there can only be one cointegrating vector. Two cointegrating vectors are interpreted as stationarity of both variables.

The Johansen technique is based on VAR. The specification includes a constant term and has no deterministic time trend. The VAR makes use of lagged values of all variables within the system. The results of the Johansen procedure differ depending on the lag length, which is in differences[27]. The optimal lag length is determined using information criteria LR, AIC and SIC. According to Yuhn (1995), if

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[25] Some weaknesses are mentioned in the discussion of the results. For an elaborate discussion see e.g. Gregory and Hansen (1996).

[26] The Johansen procedure is inter alia far more efficient and insensitive to the left hand side variable, i.e. all variables are treated symmetrically.

[27] A lag length of zero in the VECM is equivalent to VAR(1).

the true model should contain more lags, OLS outperforms the Johansen procedure.[28] Yuhn argues therefore that is advisable to fit a higher order VAR to obtain more robust results. On the other hand, every additional lag can lead to a loss of efficiency.

Re-estimating the VECM.

Furthermore, the Johansen procedure allows for testing whether restrictions imposed on the coefficient can be rejected or not. That is, the Johansen procedure allows for testing hypotheses about the equilibrium relation between the variables. To that end, the VECM is re-estimated with a predetermined number of cointegrating relations, which in this case can only be 1.

Rank determination.

When determining this number of cointegrating relations, we take into account the economic interpretability of the results. Furthermore, the analysis is accompanied with a visual inspection. If the graphs of the cointegrating relation reveal non-stationary behavior, the model specification is incorrect. For example, $I(2)$ variables are included. Appendix C provides graphs for the United Kingdom, Switzerland and Germany.

Imposing identifying and binding restrictions.

After rank determination, restrictions are imposed on the VECM. First, identifying restrictions normalize the coefficient to set the value of the nominal interest rate to unity. Because the Johansen technique is based on VAR, it has the advantage that all variables are endogenous, i.e. a simultaneous relation. Theory suggests that the nominal interest rate is the left hand side variable. When using inflation as the left hand side variable, the author obtains very implausible values for the real interest rate.

[28] Theory has little to say about the true lag length. Because of the sensitivity of the of the Johansen procedure to the lag length, it may be wise to base the selection on information criteria. Every additional lag can lead too a loss of efficiency.

These results are not reported in the paper.[29] Second, binding restrictions are imposed on the coefficient value of the inflation rate. A coefficient value equal to unity is consistent with the strong form of the Fisher effect. The implication of failing to reject this binding restriction is that inflation exhibits long-run neutrality with respect to real interest rates (Beyer, Haug and Dewald, 2009). Another implication of such a finding is that the nominal interest rate might not be a good indicator of market conditions (Mishkin, 1981). Following good econometric practice, the author performs additional tests of restrictions, i.e. tests whether coefficient values are zero.

Robustness checks.

Additional tests of restrictions suggest a way of making inference more robust in the presence of near integrated variables (Hjalmarsson and Österholm, 2007). Hjalmarsson and Österholm show that in a system with near integrated variables there is a high risk of reaching the erroneous conclusion that completely unrelated variables are cointegrated.[30] Performing additional tests of restrictions on the cointegrating vector substantially reduces the spurious rejection rate.[31] Moreover, such additional tests of restrictions may be interpreted as additional stationarity tests within the Johansen framework. Every I(0) variable in the system introduces an additional cointegrating vector. Thus, a cointegrating vector may be due to the stationarity of a variable. Therefore, the rank of the system alone cannot be taken as evidence for cointegration.

Statistical analysis and discussion.

Table 4 presents the results of the Johansen analysis. Columns (1) and (2) give the number of cointegrating relations according to the maximum likelihood test and the trace test. Column (3) gives the unrestricted estimated value of the beta coefficient.

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[29] The results have no economic interpretability.
[30] Overall, the trace statistic performs much worse than the maximum likelihood statistic.
[31] However, the rejection rate remains higher than the nominal rate.

Columns (4), (5) and (6) provide the LR test results of the imposed restrictions.

Column (7) gives the selected optimal lag length in first differences.

Table 4

Results of the Johansen analysis

Country	m	Sample	Rank L_{max} test	Rank L_{trace} test	Estimated coefficient b	LR test of restrictions			Lags in VECM
			(1)	(2)	(3)	β_π=1 (4)	β_π=0 (5)	β_i=0 (6)	(7)
United Kingdom (UK)	1	1970M3: 2010M02	1 [0.0022]	1 [0.0006]	0.4130 (0.1079)	0.0855 [0.7699]	9.9626 [0.0016]	4.6581 [0.0309]	0
	2	1970M03: 2009M02	1 [0,0000]	1 [0,0000]	0.3195 (0.0616)	5.1212 [0.0236]	6.1288 [0.0133]	10.6271 [0.0011]	0
	3	1970M03: 2008M02	1 [0.0000]	1 [0.0000]	0.3006 (0.0655)	7.0293 [0.0080]	5.5619 [0.0184]	13.1020 [0.0003]	0
	4	1970M03: 2007M02	1 [0.0000]	1 [0.0000]	0.2770 (0.0606)	13.4894 [0.0002]	7.2152 [0.0072]	22.7634 [0.0002]	0
	5	1970M03: 2006M02	1 [0.0000]	1 [0.0000]	0.2189 (0.0696)	14.4604 [0.0001]	3.3272 [0.0681]	20.3092 [0.0000]	0
Switzerland (CH)	2	1988M02: 2009M03	1 [0.0000]	1 [0.0000]	1.2898 (0.1659)	2.4213 [0.1197]	24.8350 [0.0000]	26.0729 [0.0000]	0
	3	1988M02: 2008M03	2 [0.0125]	2 [0.0125]	0.8879 (0.1978)	---	---	---	0
	4	1988M02: 2007M03	2 [0.0105]	2 [0.0105]	0.1219 (0.2752)	---	---	---	1
	5	1988M03: 2006M03	2 [0.0292]	2 [0.0292]	0.9889 (0.4649)	---	---	---	1
Germany (D)	1	1972M11: 2009M01	1 [0.0044]	1 [0.0048]	1.4549 (0.2310)	2.9256 [0.0872]	12.1461 [0.0000]	15.4906 [0.0000]	0
	2	1972M11: 2008M01	2 [0.0068]	2 [0.0068]	1.1034 (0.1792)	---	---	---	0
	3	1972M11: 2007M01	2 [0.0020]	2 [0.0020	0.6728 [0.1794]	---	---	---	0
	4	1972M11: 2006M01	2 [0.0050]	2 [0.0050]	0.4306 (0.1841)	---	---	---	0
	5	1972M11: 2005M01	2 [0.0477]	2 [0.0477]	0.2641 (0.2310)	---	---	---	0

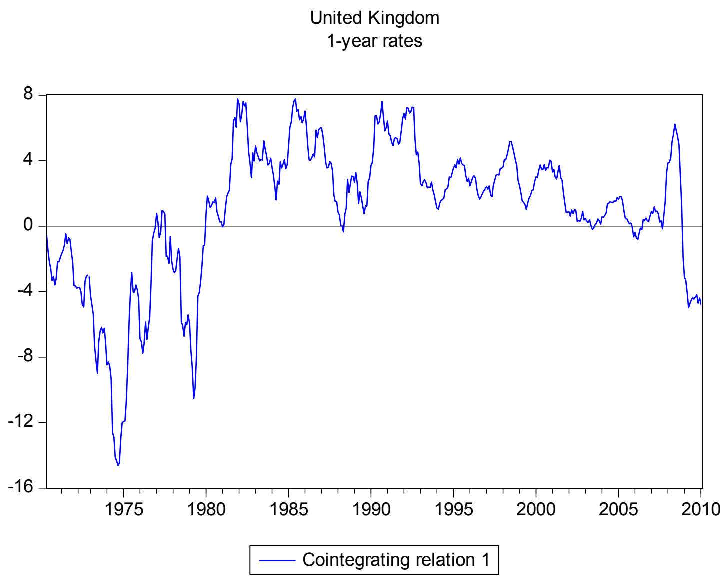
Note. The trace test has H_0: ≤ r versus H_a: >r ; the hypotheses for the maximum likelihood test are H_0: r and H_a: r+1, where the rank *r* is the number of cointegrating vectors. In column (2) and (3) the values within brackets indicate the probability values under the rejected null hypothesis. The LR test of restrictions is performed when re-estimating the VECM with one cointegrating relation. β_π=1 represents a test of the strong form of the Fisher hypothesis. β_π=0 may be interpreted as a stationarity test of the nominal interest rate. β_i=0 may be interpreted as a stationarity test of the inflation rate. The optimal lag length is selected using information criteria LR, AIC and SIC. Zero lagged differences in the VECM is equivalent to VAR(1). Standard errors of coefficients in parentheses. Probability values within brackets.

United Kingdom.

For the United Kingdom both the maximum likelihood and the trace test results indicate the presence of 1 cointegrating vector. The significance of this result seems to increase with maturity. The estimate of the beta coefficient ranges from 0.4130 to 0.2189. The estimate is highest for the 1-year rates and decreases with maturity.

The LR test of restrictions is performed after re-estimating the VECM with one cointegrating relation. The produced results for the United Kingdom are plausible and economically interpretable[32].

Graph 1 shows the cointegrating relation or error of the UK 1-year rates.[33] To the author's subjective judgment the linear combination is stationary. The graph gives no indication of an incorrect model specification.



Graph 1. This figure shows the deviations or error from the long-run equilibrium relationship between UK 1-year rates.

The graph shows large deviations from the long run value, which does not offer strong support for a cointegrating relation. Other graphs of the United Kingdom provided in appendix C, all display the same pattern of large negative deviations until

[32] This judgment is also based on the estimates of the real interest rate (the constant term). For the sake of brevity and clarity these results are not reported in the table.
[33] For the sake of brevity only the graph of the 1-year is discussed in the text. A full overview of graphs is given in Appendix C.

1980 and large positive deviations thereafter. A structural break seems to occur around 1980.

Previously, the Gregory-Hansen test found cointegration in the presence of a regime shift that occurs around 1980. However, detecting structural breaks by visual inspection and relying on other tests is questionable. As noted, Carrion-i-Sylvestre and Sans (2006) developed a test that is capable of detecting a structural break within the Johansen framework.[34] This is an interesting approach, because in the literature it is found that the Fisher effect is nor robust for policy changes (Yuhn, 1995).

Table # shows that only in the case of the UK 1-year rates we cannot reject the restriction that nominal interest rates and inflation move one to one, which is consistent with the strong form of the Fisher effect. In that case, money is super-neutral to inflation, i.e. inflation exhibits long run neutrality with respect to the real interest rate (Beyer, Haug and Dewald, 2009). [35]

Furthermore, the LR test of restrictions suggests that the UK 5-year inflation rate can be excluded from the cointegrating vector. Under the null of one cointegrating relation, this suggests the stationarity of the UK 5-year nominal interest rate, which is consistent with previous findings of the ZAURoot test. Thus, there is in fact no cointegration between the UK 5-year rates.[36]

The information criteria suggest an optimal lag length of zero. Zero lags in first differences (VECM), correspond with one lag in levels (VAR). Little confidence can be put on results based on 1 or 2 lags (Gonzalo, 1994). In all cases, adding lags strengthens the conclusion that there is no cointegration.

[34] This test is not available to the author and therefore remains outside the scope of this paper.

[35] Therefore, a specific definition of the Fisher hypothesis is that there should be no correlation between real interest rates and inflation.

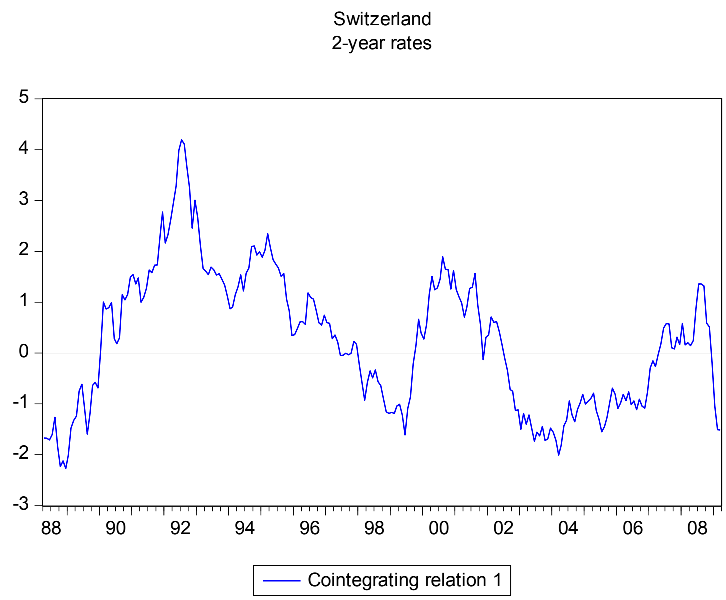
[36] The cointegrating vector is due to the stationarity of the 5-year UK nominal interest rate.

Switzerland.

For Switzerland the maximum likelihood test and the trace test suggest that there is highly significant cointegrating relation between the CH 2-year rates. In the case of the CH 3-year, 4-year and 5-year rates, both tests indicate a rank equal to the number of variables, which is 2. This means that all variables are stationary.

The estimates of the unrestricted beta coefficient range from 1.2898 to 0.1219. A V-shaped pattern is observed. Again the estimate is highest for the shortest maturity (2 years). However, the beta estimate is only relevant if there is a unique cointegrating relation, such as between the 2-year rates.

When re-estimating the VECM with 1 cointegrating vector we again take into account that the produced results are plausible and economically interpretable. Moreover, from Graph 2 it becomes clear that the linear combination is stationary. The deviations from the long run equilibrium relationship are small in comparison with the deviations in the United Kingdom.



Graph 2. This figure shows the deviations or error from the long-run equilibrium relationship between CH 2-year rates.

The binding restriction that the slope coefficient equals 1 cannot be rejected. This is support for the strong form of the Fisher hypothesis. Moreover, the LR test of restrictions strongly rejects the stationarity of both CH 2-year rates.

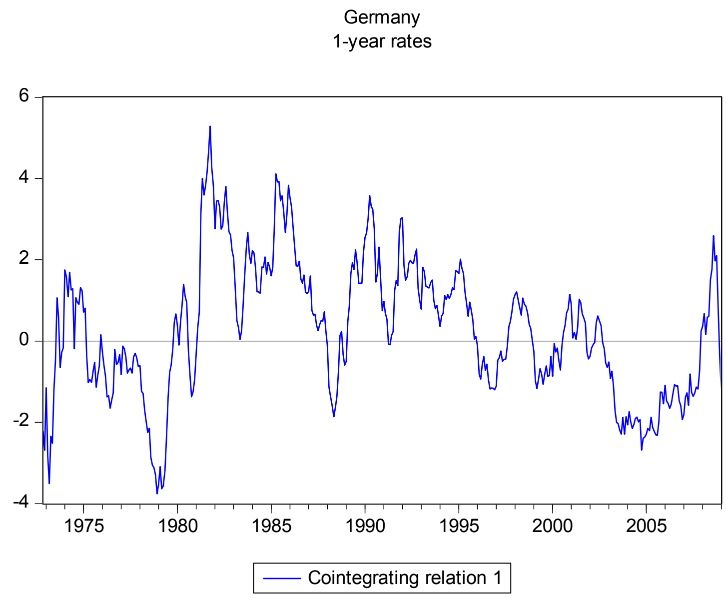
Table 4 presents the results based on the optimal lag length according to SIC. Again, the results are not robust as they are extremely sensitive to the chosen lag length. Additional lags invalidate the conclusion that there is cointegration between the CH 2-year rates.

Germany.

Similar results are obtained for Germany. Both the maximum likelihood and the trace test suggest a long-run relationship between the D 1-year inflation rate and nominal interest rate. In all other cases, two cointegrating vectors are identified, which suggests that the D 2-year, 3-year, 4-year and 5-year variables all are stationary. This is consistent with results of the KPSS stationarity test.

The estimates of the unrestricted slope coefficient vary between 1.4549 and 0.2641. The same pattern as in the United Kingdom is observed. The estimate of the slope coefficient is highest for the 1-year rates and decreases with maturity.
When re-estimating the VECM with 1 cointegrating vector, the author again performs a visual inspection to rule out errors in the model specification. Graph 3 displays the cointegrating relation between the 1-year rates.

The author judges that the cointegrating relation displayed in the graph is stationary. The deviations from the long-run equilibrium value are similar in magnitude to the ones in Switzerland (Graph #). However, in Germany the deviations seem more volatile. The distance between the peaks and downs in the graph is much smaller than in Switzerland.



Graph 3. This figure shows the deviations or error from the long-run equilibrium relationship between D 1-year rates.

The imposed restrictions that the slope coefficient is equal to 1 cannot be rejected. Thus, the German 1-year inflation rate and nominal interest rate cointegrate with a slope coefficient of 1.

Again, the results are very sensitive to the lag length. The information criteria suggest an optimal lag length of zero, so no lag in differences is included in the VECM. Again, little confidence can be put in the results from short lag lengths (Gonzalo, 1994). Adding lags weakens the conclusion that there is cointegration. Or put it another way, the lack of robustness strengthens the conclusion that there is no cointegration.

Peng (1995) argues that the strong anti-inflation commitment by the monetary authority in Germany has contributed to a weaker Fisher effect, as inflation is low and less persistent. In fact, the monetary policy regimes in all three countries under consideration have gained enough credibility to maintain inflation within the desired range. Their influence may be carried through to the long-term rates, weakening the Fisher effect (Mitchell-Innes, 2006).

The differences with the findings of Engsted (1995) may be explained by differences in time span, frequency of the data and maturity of the government bonds. Moreover, the author makes use of data for Germany based on the method by Svensson (1994).

Conclusion

The evidence of the integration properties of the inflation and interest rate is very mixed. In the light of this finding one could question the statement that the Fisher effect is best interpreted as a long-run relationship. When proceeding with the cointegration tests, on balance the test results suggest that there is no cointegration between the variables under investigation. Thus, based on the results obtained from the Gregory-Hansen test and Johansen procedure – that complement each other - there is little support for the long-run Fisher effect. Most findings do not pass the robustness checks. There is very little empirical support for a long-run equilibrium relationship between inflation and nominal interest rates.

An implication of this finding is that money is not super-neutral, because in the long run real interest rates may be affected by inflation. Another implication is that nominal interest rates probably are a good indicator of financial market conditions, as movements in the nominal interest rates may reflect movements in the real interest rates.

However, the finding of no cointegration may be due to the failure to identify structural breaks within the Johansen framework. After identification of the breakpoints, a suggestion would be to divide the sample in subsamples. However, one should make sure that the structural break is consistent with the Fisher hypothesis.

Therefore, structural breaks should be identified properly by offering mechanistic explanations. It is not sufficient to associate the breakpoint with an event. This is a direction for future research.

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Appendix

Appendix A

Table A

Descriptive statistics

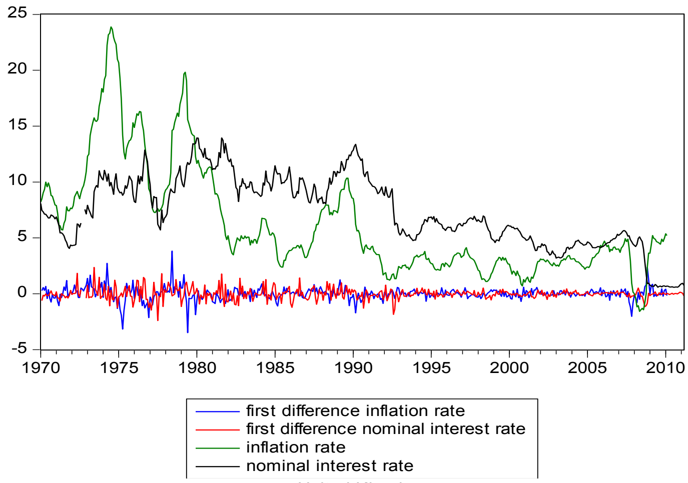
Country	m		Mean	Median	Maximum	Minimum	SD	N
United	1	i	7.3307	6.8711	13.9376	0.5776	3.1734	493
Kingdom		π	6.5615	4.4255	23.8843	0.6945	5.0884	434
(UK)	2	i	7.5010	7.3522	14.0776	0.7677	3.0692	493
		π	6.4932	4.5861	19.8265	1.4686	4.7845	434
	3	i	7.6426	7.7647	14.2063	1.0746	3.0143	493
		π	6.4344	4.5785	18.2182	1.7766	4.5898	434
	4	i	7.7524	7.9584	14.3979	1.4124	2.9856	493
		π	6.3454	4.5682	16.8865	1.8680	4.4394	434
	5	i	7.8441	8.1055	14.4455	1.7422	2.9718	493
		π	6.2342	4.5735	15.3262	2.0754	4.3018	434
Switzerland	2	i	2.9360	2.3765	7.5395	0.3464	1.9922	279
(CH)		π	1.7532	1.1614	5.8254	0.0510	1.5788	219
	3	i	3.0210	2.5180	7.0552	0.4311	1.7928	279
		π	1.6738	1.0364	5.1880	0.3072	1.4363	219
	4	i	3.1373	2.7450	6.8994	0.5246	1.6663	279
		π	1.5532	0.9526	4.7153	0.4616	1.2585	219
	5	i	3.2551	2.9054	6.8107	0.5246	1.6663	279
		π	1.4434	0.9250	4.3259	0.6473	1.0860	219
Germany	1	i	5.2146	4.6263	12.3721	0.5087	2.3813	450
(D)		π	2.8310	2.4888	7.4827	-1.1609	1.8614	388
	2	i	5.44933	5.0027	11.6271	0.9257	2.2435	450
		π	2.7499	2.2892	6.6947	-0.0828	1.6779	388
	3	i	5.6709	5.4062	11.3329	1.3706	2.15379	450
		π	2.6857	2.1037	6.2546	0.2746	1.5204	388
	4	i	5.8522	5.6380	11.1184	1.7840	2.0814	450
		π	2.6365	2.1589	5.6076	0.7655	1.3808	388
	5	i	5.9993	5.8269	10.8765	2.1468	2.0191	450
		π	2.5861	2.0246	5.1935	1.0207	1.2690	388

Note. The *m* column indicates the maturity in years. The nominal interest rate is denoted by *i.* The inflation rate is denoted by π. SD stands for the standard deviation an N is the number of observations in the sample.

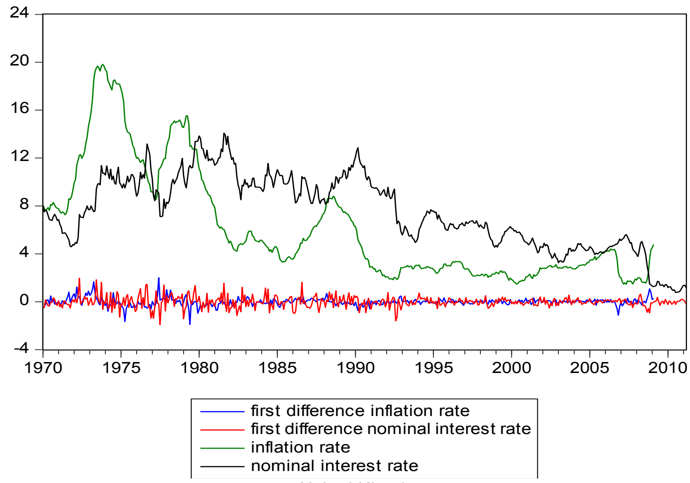
Appendix B: Graphs of the Nominal Interest Rate and Inflation Rate

United Kingdom

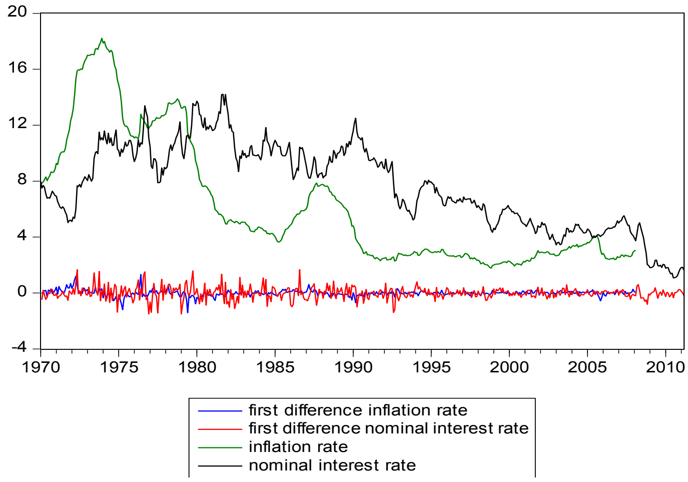
United Kingdom
1-year rates



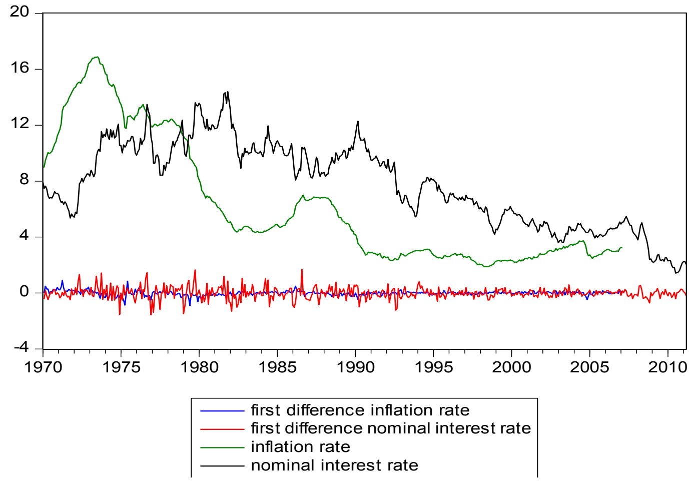
United Kingdom
2-year rates



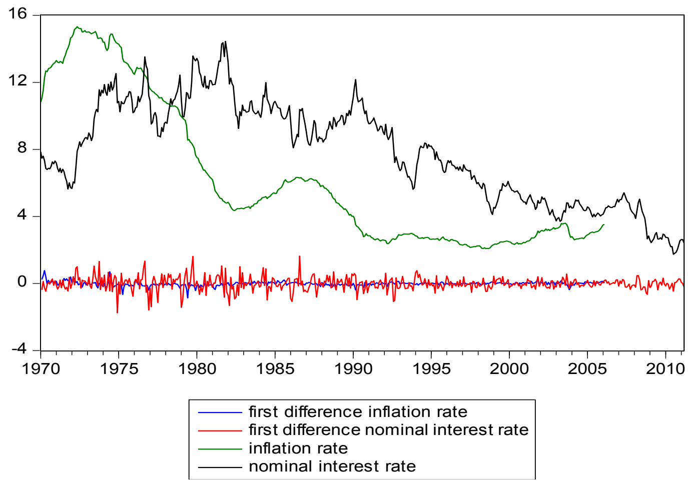
United Kingdom
3-year rates



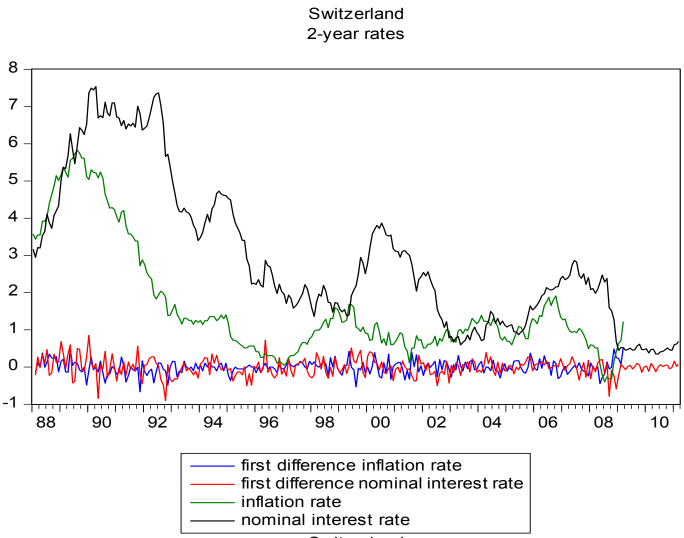
United Kingdom
4-year rates

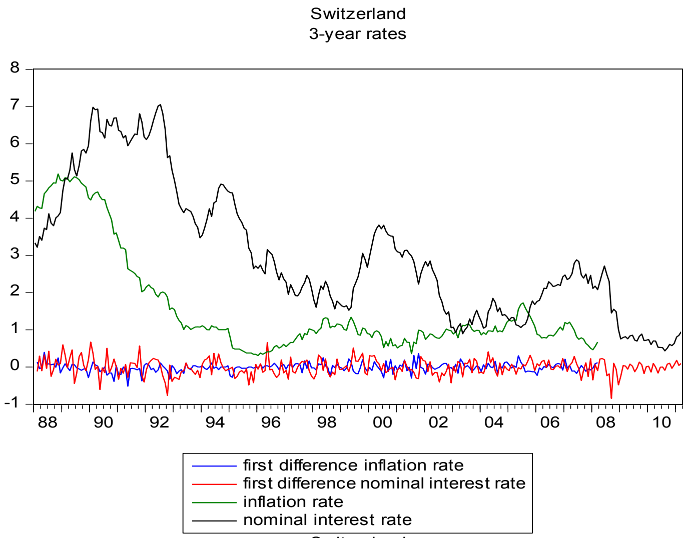


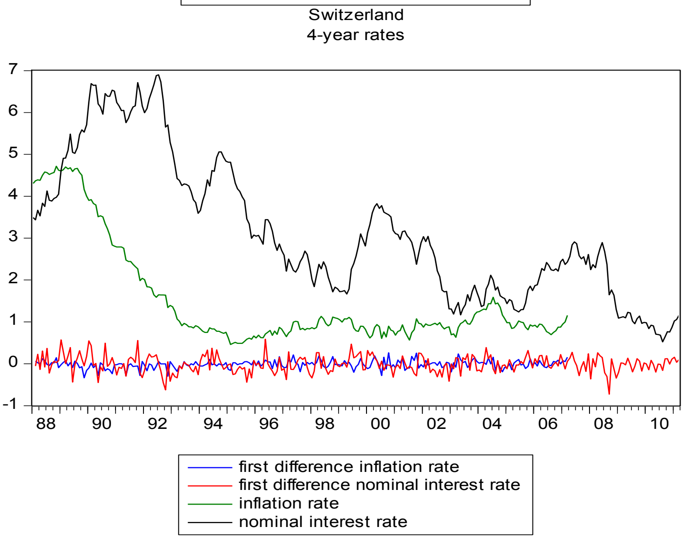
United Kingdom
5-year rates

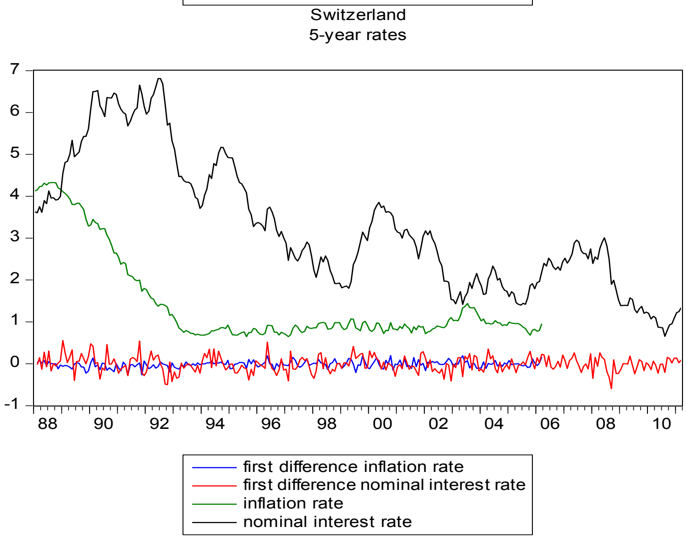


Switzerland

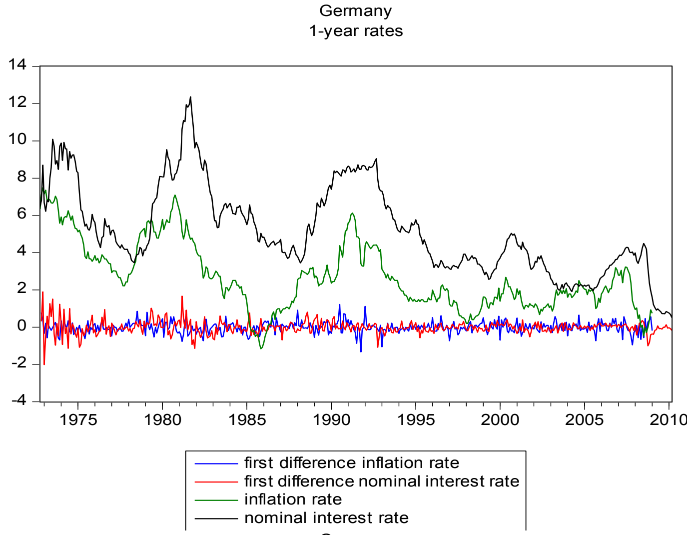


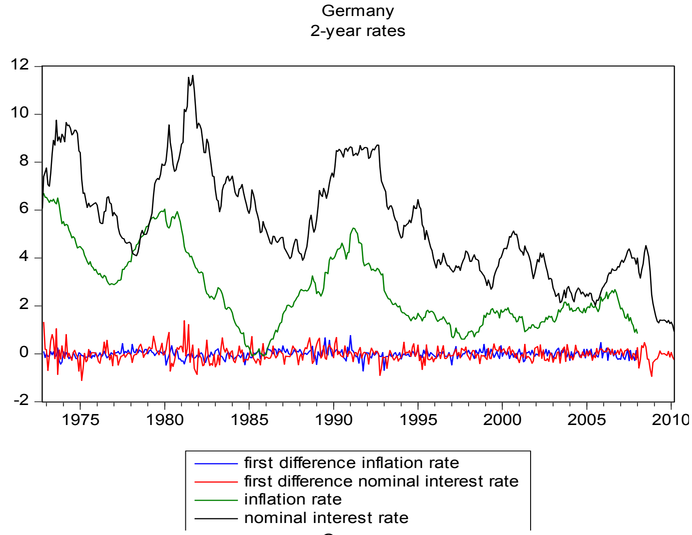


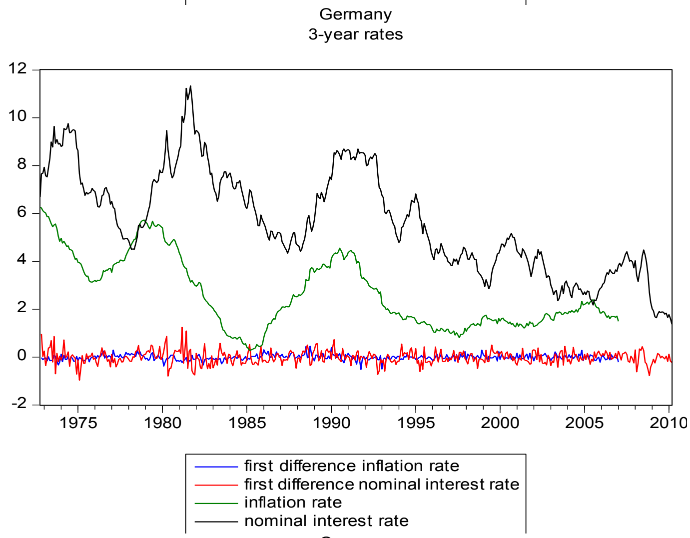


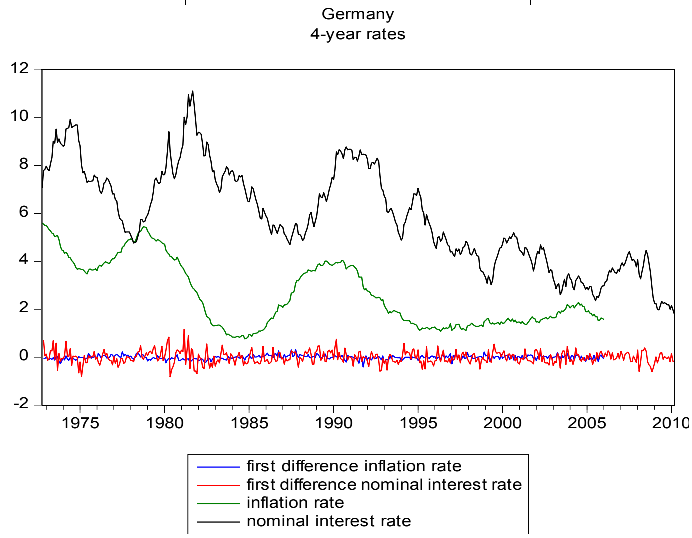


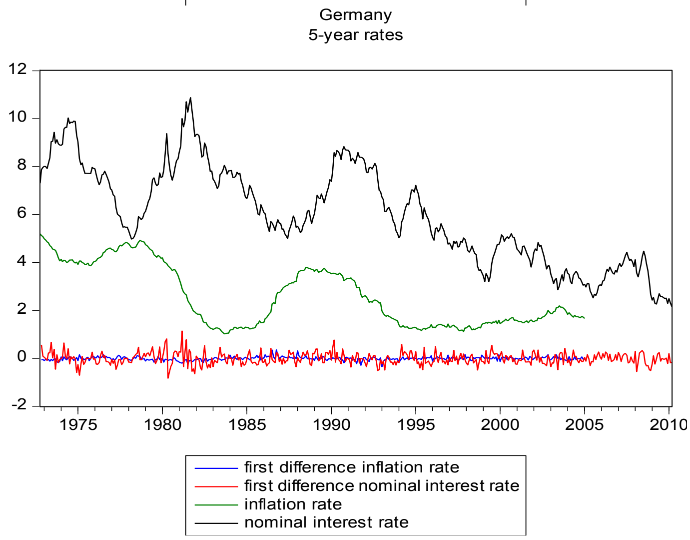
Germany


Germany
1-year rates
14
12
10
8
6
4
2
0
-2
-4
1975
1980
1985
1990
1995
2000
2005
2010
first difference inflation rate
first difference nominal interest rate
inflation rate
nominal interest rate


Germany
2-year rates
12
10
8
6
4
2
0
-2
1975
1980
1985
1990
1995
2000
2005
2010
first difference inflation rate
first difference nominal interest rate
inflation rate
nominal interest rate

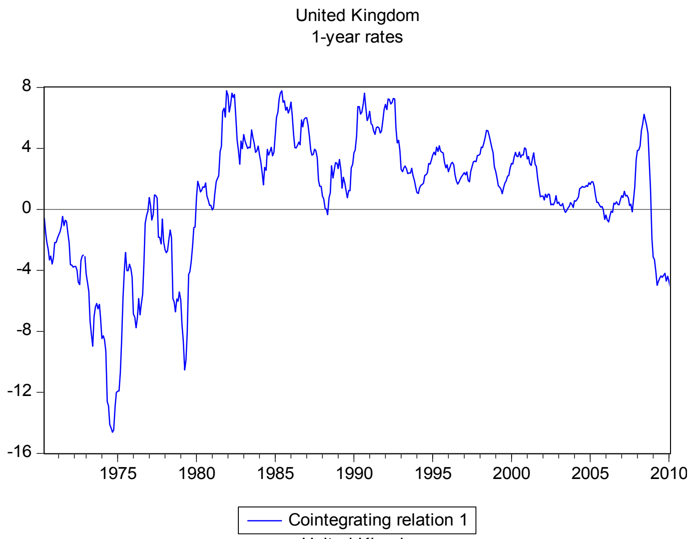

Germany
3-year rates
12
10
8
6
4
2
0
-2
1975
1980
1985
1990
1995
2000
2005
2010
first difference inflation rate
first difference nominal interest rate
inflation rate
nominal interest rate

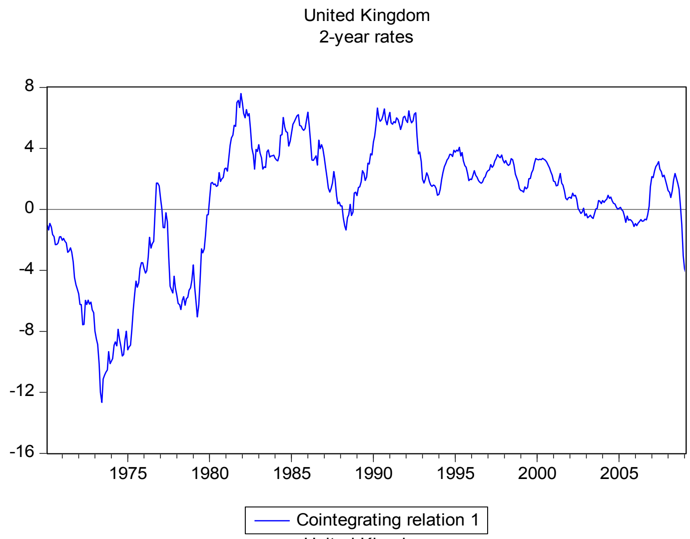

Germany
4-year rates
12
10
8
6
4
2
0
-2
1975
1980
1985
1990
1995
2000
2005
2010
first difference inflation rate
first difference nominal interest rate
inflation rate
nominal interest rate

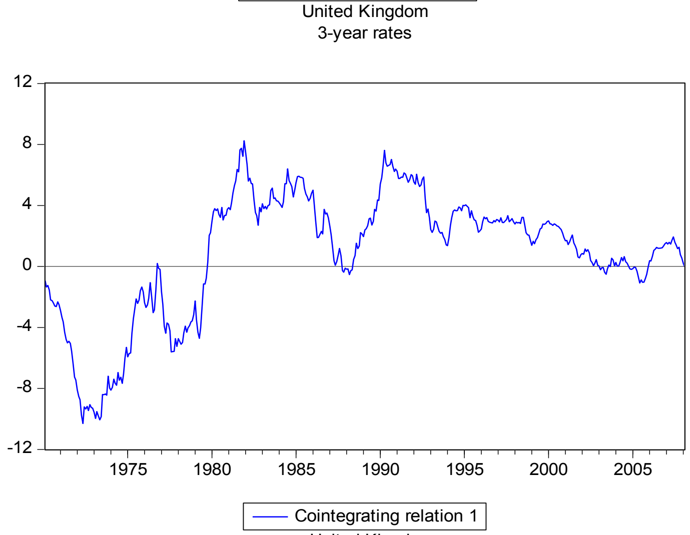

Germany
5-year rates
12
10
8
6
4
2
0
-2
1975
1980
1985
1990
1995
2000
2005
2010
first difference inflation rate
first difference nominal interest rate
inflation rate
nominal interest rate

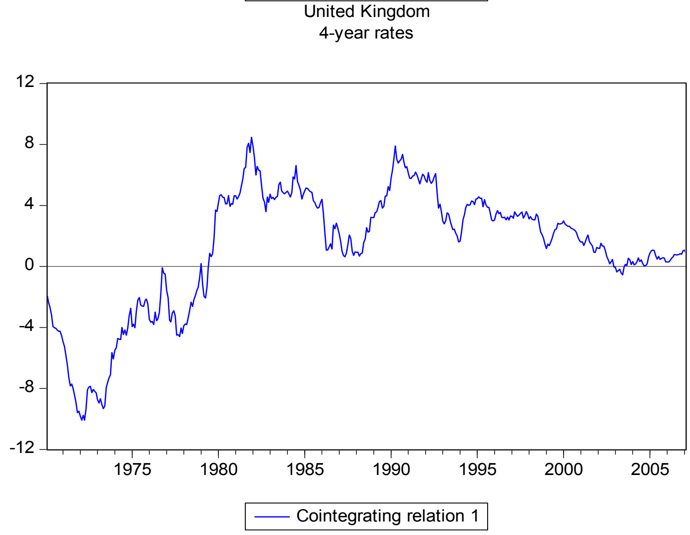
Appendix C: Graphs of the Cointegrating Relation

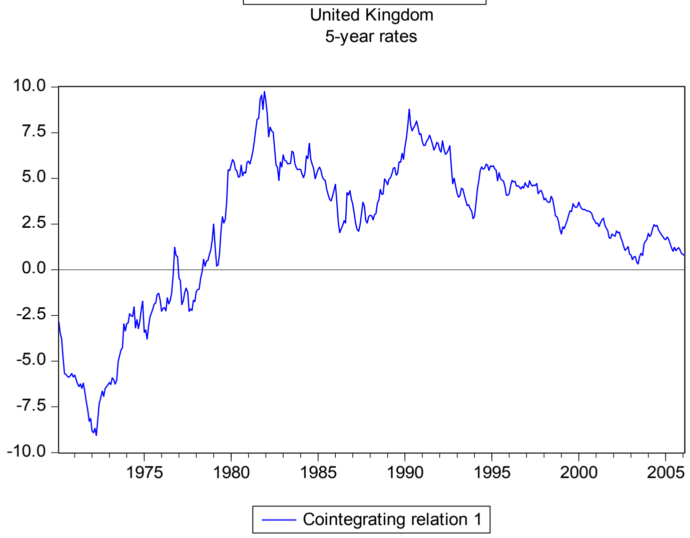
United Kingdom



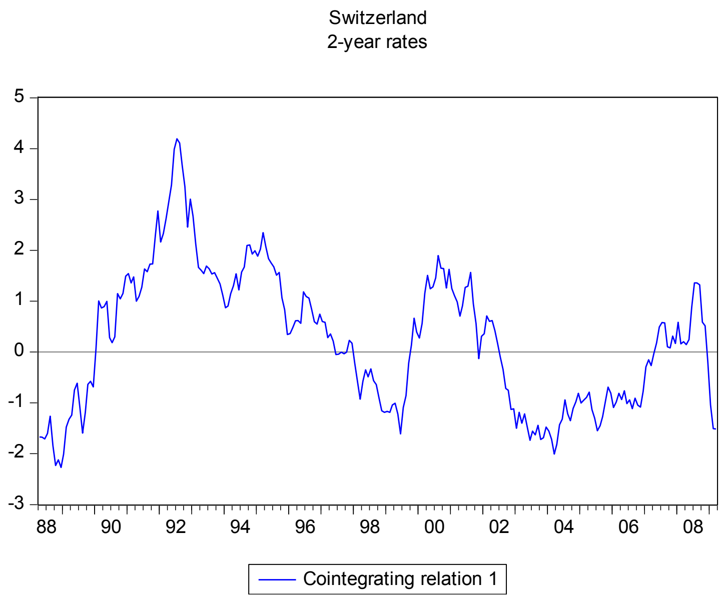




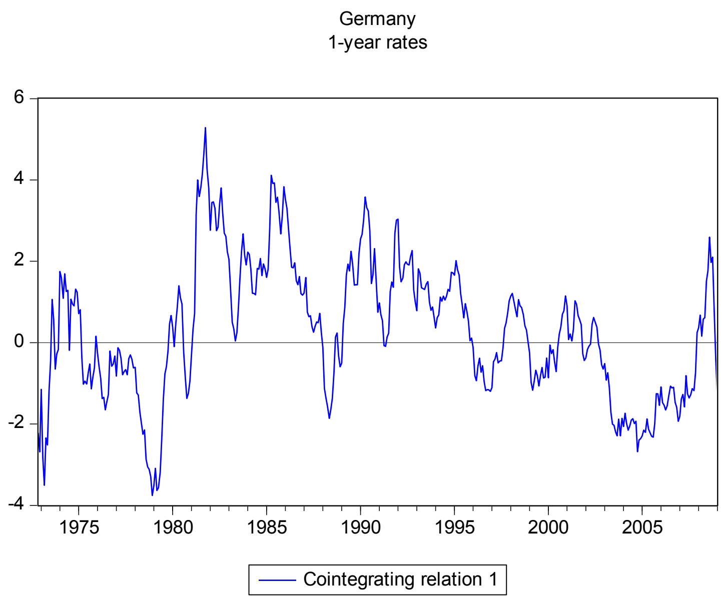




Switzerland



Germany



Appendix D

ZAURoot Test

```
'Zivot-Andrews Unit Root Test
'Reference: Zivot, E. and Andrews, D. W. K. (1992), "Further Evidence on the Great Crash,
the Oil-Price Shock, and the Unit-Root Hypothesis", Journal of Business & Economic
Statistics, Vol. 10, No. 3, pp. 251-270.

call divot(y,"C",4)

' ----------------------------------------------------------------------------------------------------
' Arguments
'-----------------------------------------------------------------------------------------------------
'series Y             ' dependent variable
'scalar Maxlag        ' Maximum number of lags for unit root testing
'string %Model        ' Location of the break ("A" = Intercept, "B" = Trend, "C" = Both)
' ----------------------------------------------------------------------------------------------------

subroutine zivot(series y,string %Model,scalar maxlag)
!trim = 0.15 'Trimming parameter
series DY = D(Y)

!nobs = @obs(y)-maxlag-1

smpl @first+maxlag+1 @last
equation temp.ls dy c @trend y(-1)
!aic0 = log(temp.@ssr/!nobs)+2*(temp.@ncoef/!nobs)
!bic0 = log(temp.@ssr/!nobs)+ log(!nobs)*(temp.@ncoef/!nobs)
!min_aic = !aic0

for !lag=maxlag to 1 step -1
  equation temp.ls dy y(-1) c @trend dy(-1 to -!lag)
  !aic = log(temp.@ssr/!nobs)+2*(temp.@ncoef/!nobs)
  !bic = log(temp.@ssr/!nobs)+log(!nobs)*(temp.@ncoef/!nobs)
      if !aic < !min_aic then
       !min_aic = !aic
       !best_lag = !lag
        else if !min_aic = !aic0 then
        !best_lag =0
        endif
     endif
next

smpl @all
!znobs = @obs(y) - !best_lag
!lower = 1+!best_lag+@round(!znobs*!trim)
!upper =  @obs(y)-@round(!znobs*!trim)

vector(!upper-!lower+1) results

smpl @first + !best_lag @last
for !i = !lower to !upper
  if !best_lag=0 and %Model = "A" then
     equation temp.ls DY Y(-1) C @trend (@trend>!i-2)
     else if !best_lag=0 and %Model = "B" then
        equation temp.ls DY Y(-1) C @trend (@trend>!i-2)*(@trend-!i+2)
       else if !best_lag=0 and %Model = "C" then
          equation temp.ls DY Y(-1) C @trend (@trend>!i-2) (@trend>!i-2)*(@trend-!i+2)
```

```
        else if !best_lag>0 and %Model = "A" then
          equation temp.ls DY Y(-1) C @trend (@trend>!i-2) DY(-1 to -!best_lag)
          else if !best_lag>0 and %Model = "B" then
            equation temp.ls DY Y(-1) C @trend (@trend>!i-2)*(@trend-!i+2) DY(-1 to -
!best_lag)
            else if !best_lag>0 and %Model = "C" then
              equation temp.ls DY Y(-1) C @trend (@trend>!i-2) (@trend>!i-2)*(@trend-!i+2)
DY(-1 to -!best_lag)
            endif
          endif
        endif
      endif
    endif
  endif
  results(!i-!lower+1) = temp.@tstats(1)
next

vector t_min =@min(results)
!t_min = t_min(1)

vector break
  !i =1
    while !i<=!upper-!lower+1
     if results(!i) = @min(results) then
       break = !i+!lower-1
     endif
       !i = !i+1
    wend

!break = break(1)

          series DT = (@trend>!break-2)*(@trend-!break+2)
            if %Model = "A" or %Model="C" then
              series DU = @trend> !break-2
            endif
        if !best_lag=0 and %Model="A" then
          equation ZA.ls DY Y(-1) C @trend DU 'Selected equation
          else if !best_lag=0 and %Model="B" then
            equation ZA.ls DY Y(-1) C @trend DT 'Selected equation
              else if !best_lag=0 and %Model="C" then
                equation ZA.ls DY Y(-1) C @trend DU DT 'Selected equation
                  else if !best_lag>0 and %Model = "A" then
                    equation ZA.ls DY Y(-1) C @trend DU DY(-1 to -!best_lag) 'Selected equation
                    else if !best_lag>0 and %Model = "B" then
                      equation ZA.ls DY Y(-1) C @trend DT DY(-1 to -!best_lag) 'Selected equation
                        else if !best_lag>0 and %Model = "C" then
                          equation ZA.ls DY Y(-1) C @trend DU DT DY(-1 to -!best_lag) 'Selected
equation
                        endif
                    endif
                  endif
                endif
          endif
        endif

table(6,2) ZAZ
ZAZ(1,1) = "Variable(s)"
ZAZ(3,1) = "t-stat(s)"
ZAZ(4,1) = "Lag(s)"
ZAZ(5,1) = "Break"
```

```
ZAZ(6,1) = "DU1 p-value"
ZAZ(1,2) = y.@name
ZAZ(3,2) = !t_min
ZAZ(4,2) = !best_lag
ZAZ(5,2) = @otod(!break)
ZAZ(6,2) = @tdist(za.@tstat(4),za.@regobs-za.@ncoef)
setline(ZAZ, 2)
show ZAZ
smpl @all

delete temp break results t_min
endsub
```

Gregory-Hansen Cointegration Test

```
'Gregory-Hansen Cointegration Test
'Reference: Gregory, A. W. and Hansen, B. E. (1996). "Residual-Based Tests for
Cointegration in Models with Regime Shifts", Journal of Econometrics, Vol. 70, pp. 99-126.

call greghansen(y,x,2,"aic",6)

' ---------------------------------------------------------------------------------------------------
' Arguments
'---------------------------------------------------------------------------------------------------
'series Y             ' dependent variable
'group G              ' group of independent variable(s) (including single series)
'scalar Model         ' 2 = Level Shift, 3 = Level Shift with Trend, 4 = Regime Shift
'scalar Maxlag        ' Maximum number of lags for unit root testing
'string %Criterion    ' Selection criteria for unit root testing (i.e. aic / sic / hqc)
' ---------------------------------------------------------------------------------------------------

subroutine greghansen(series Y, group G, scalar Model, string %Criterion, scalar Maxlag)
smpl @all
!trim = 0.15
!maxlag = Maxlag

!n = @obs(y)
!nindep = G.@count

!lower = @round(@obs(Y)*!trim)
!upper = @round(@obs(Y)*(1-!trim))
matrix(!upper-!lower+1,4) GHtest

equation ghc

Table GHZ
GHZ(1,1) =  "THE GREGORY-HANSEN"
GHZ(2,1) = "COINTEGRATION TEST"
if Model=2 then GHZ(3,1) = "MODEL 2: Level Shift"
else if Model =3 then GHZ(3,1) = "MODEL 3: Level Shift with Trend"
  else if Model = 4 then GHZ(3,1) = "MODEL 4: Regime Shift"
  endif
endif
endif
GHZ(5,1) = "ADF Procedure"
GHZ(7,1) = "t-stat"
GHZ(8,1) = "Lag"
GHZ(9,1) = "Break"
GHZ(11,1) = "Phillips Procedure"
GHZ(13,1) = "Za-stat"
```

```
GHZ(14,1) = "Za-break"
GHZ(15,1) = "Zt-stat"
GHZ(16,1) = "Zt-break"

for !ref = 2 to 4
  GHZ.setwidth(!ref) 15
next

GHZ.setlines(a4:b4) +d
GHZ.setlines(a6:b6) +d
GHZ.setlines(a10:b10) +d
GHZ.setlines(a12:b12) +d

for !i = !lower to !upper

  if Model=2 then
   'MODEL 2 - C: LEVEL SHIFT MODEL
    ghc.ls Y c G (@trend>!i-2)
    ghc.makeresid res
    uroot(adf, none, info={%criterion}, maxlag=!maxlag, save=level) res
    GHtest(!i-!lower+1,1) = level(3,1)
    GHtest(!i-!lower+1,2) = level(2,1)
    call phillips(res)
    GHtest(!i-!lower+1,3) = !Za
    GHtest(!i-!lower+1,4) = !Zt

   else if Model=3 then
   'MODEL 3 - C/T: LEVEL SHIFT WITH TREND MODEL
    ghc.ls Y c @trend G (@trend>!i-2)
    ghc.makeresid res
    uroot(adf, none, info={%criterion}, maxlag=!maxlag, save=level) res
    GHtest(!i-!lower+1,1) = level(3,1)
    GHtest(!i-!lower+1,2) = level(2,1)
    call phillips(res)
    GHtest(!i-!lower+1,3) = !Za
    GHtest(!i-!lower+1,4) = !Zt

   else if Model = 4 then
   'MODEL 4 - C/S: REGIME SHIFT MODEL
      for !g = 1 to !nindep
        G.add (@trend>!i-2)*G(!g)
      next
    ghc.ls Y c (@trend>!i-2) G
    ghc.makeresid res
    uroot(adf, none, info={%criterion}, maxlag=!maxlag, save=level) res
    GHtest(!i-!lower+1,1) = level(3,1)
    GHtest(!i-!lower+1,2) = level(2,1)
    call phillips(res)
    GHtest(!i-!lower+1,3) = !Za
    GHtest(!i-!lower+1,4) = !Zt
      for !g = G.@count to !nindep+1 step -1
       %name = G.@seriesname(!g)
        G.drop {%name}
      next
    endif
   endif
  endif
next
    vector min_t_lag = @cmin(GHtest)
    vector break = @cimin(GHtest)
```

```
    GHZ(7,2) = min_t_lag(1)
    GHZ(8,2) = GHtest(break(1),2)
    GHZ(13,2) = min_t_lag(3)
    GHZ(15,2) = min_t_lag(4)

   if @datestr(@now,"F") = "?" then
    GHZ(9,2) = break(1) + !lower - 2
    GHZ(14,2) = break(3) + !lower - 2
    GHZ(16,2) = break(4) + !lower - 2
   else
    GHZ(9,2) = @otod(break(1) + !lower - 2)
    GHZ(14,2) = @otod(break(3) + !lower - 2)
    GHZ(16,2) = @otod(break(4) + !lower - 2)
   endif

    show GHZ

delete res level GHtest break min_t_lag
endsub

subroutine phillips(series y) 'MATLAB code of this routine is available at Bruce E. Hansen's
website: http://www.ssc.wisc.edu/~bhansen/progs/joe_96.html
!n = @obs(y)
equation eq1.ls y y(-1)
!be = eq1.@coefs(1)
series ue = y - !be*y(-1)

'Bandwidth selection
!nu = @obs(ue)
equation eq2.ls ue ue(-1)
!bu = eq2.@coefs(1)
series uu = ue - !bu*ue(-1)
!su = @sumsq(uu)/@obs(uu)
!a2 = (4*!bu^2*!su/(1-!bu)^8)/(!su/(1-!bu)^4)
!bw =1.3221*((!a2*!nu)^0.2)

!pi = @acos(-1)
!j=1
!lemda = 0
    while !j <= !bw
      series temp = ue*ue(-!j)
      !gama =  @sum(temp)/!nu
      !w=(75/(6*!pi*!j/!bw)^2)*(@sin(1.2*!pi*!j/!bw)/(1.2*!pi*!j/!bw)-@cos(1.2*!pi*!j/!bw))
      !lemda=!lemda+!w*!gama
      !j=!j+1
    wend

series temp = y*y(-1) - !lemda
!p = @sum(temp)/@sumsq(y(-1))
!Za = !n*(!p-1)
!Zt = (!p-1)/@sqrt((2*!lemda + @sumsq(ue)/!nu)/(@sumsq(y(-1))))
smpl @all
delete eq1 eq2 ue uu temp
endsub
```