Policy Coordination and Risk Premium in Foreign Exchange Markets for Major EU Currencies

Chanwit Phengpis
Department of Finance
College of Business Administration
California State University, Long Beach
Long Beach, CA 90840
Phone: (562) 985-1581
Fax: (562) 985-1754
E-mail: pchanwit@yahoo.com

Vanthuan Nguyen
Department of Economics and Finance
Fairleigh Dickinson University
285 Madison Avenue, M-MS2-02
Madison, NJ 07940, USA
Phone: (973) 443-8141
E-mail: vnguyen@fdu.edu

Current Version: February 27, 2007.

*Corresponding Author

Policy Coordination and Risk Premium in Foreign Exchange Markets for Major EU Currencies

Abstract

This study updates and extends prior studies related to policy coordination and the risk premium in foreign exchange markets. It specifically examines (1) if spot exchange rates for the Danish krone, British pound, and Swedish krona have long-run equilibrium or cointegrating relationships with the euro after the EMU inception in January 1999; (2) if the presence/absence of the relationships actually reflects the differing degree of monetary interdependence of Denmark, the U.K. and Sweden with the EMU; and (3) if the relationships can represent the risk premium to foreign exchange market participants. The results suggest that only the krone and the pound are cointegrated with the euro. Additional tests of inflation convergence and further analyses of reduced-form and structural VARs indicate that the cointegration evidence indeed reflects the relatively stronger degree of monetary policy coordination and at least the *de facto* fixed exchange rate regime of Denmark and the U.K. with the EMU. Additionally, cointegration of spot exchange rates can be considered one of the factors that represent the risk premium due to its significant explanatory power for the return to forward speculation.

Policy Coordination and Risk Premium in Foreign Exchange Markets for Major EU Currencies

1. Introduction

The relationships among spot exchange rates have been of considerable interest to researchers, policymakers, and foreign exchange market participants. The majority of prior studies (e.g., MacDonald and Taylor, 1989; Lajuanie and Naka, 1992; Rapp and Sharma, 1999) find no evidence of long-run equilibrium relationships, as measured by cointegrating relationships, among spot exchange rates of various currencies over the modern float. However, as policymakers in different countries closely and consistently coordinate their monetary policies to considerably limit fluctuation of the exchange rate of one currency relative to another, a *de facto* fixed regime results.[1] In this case, their spot exchange rates (expressed in terms of a numeraire currency such as the U.S. dollar) may be cointegrated because the currency prices cannot permanently diverge from each other.

An obvious example of a de *facto* fixed regime is a group of European Union (EU) currencies. Haug MacKinnon and Michelis (2000) and Rangvid and Sorensen (2002) detect cointegrating relationships among spot exchange rates for several EU currencies over the periods preceding the inception of the European Economic and Monetary Union (EMU) in January 1999. This finding is consistent with the fact that the Maastricht Treaty and the Exchange Rate Mechanism (ERM), among other measures, require considerable alignment and convergence of key economic variables of EU countries such as inflation rates and exchange rates before they can become EMU members and adopt the euro as their currency.

[1] Of course, if the allowable fluctuation is very close to zero, a truly fixed regime results. Because a central bank has a monetary policy choice between domestic prices and the exchange rate, the choice under a fixed regime is obviously the exchange rate.

To date, Denmark, the U.K., and Sweden are major EU countries which are not EMU members and hence still retain their national currencies. Denmark has been part of the ERM II since January 1999. Specifically, the Danish krone is pegged to the euro at a central rate with a ±2.25% fluctuation band.[2] This considerably narrow band signifies a truly fixed exchange rate regime and implies strong monetary interdependence between Denmark and the EMU. The fixed regime also suggests that a cointegrating relationship between the krone and the euro is highly likely.

Further, the U.K. conducted the "Five Economic Tests" to evaluate its readiness for becoming an EMU member. The test results published in 2003 indicate that the U.K. did make significant progress towards cyclical convergence in inflation rates, long-term interest rates, and government deficits and debt. However, it decided that it was not ready to join the EMU because the cyclical convergence might not be sustainable and because other structural differences between the U.K. and EMU economies still transpired. Currently, the U.K. is committed to adopting various policies and reforms to further improve the convergence, especially inflation, and to make its economic structures increasingly compatible with the EMU for possible future membership.[3] As a result of these efforts, the *de facto* fixed regime between the British pound and the euro may exist and the two currencies may be cointegrated even though the pound is officially under the freely floating regime.

In contrast, Sweden does not have specific policy mandates which require its key economic variables to be necessarily aligned with those of the EMU. Therefore, the Swedish central bank's indication that its monetary policy is based on its own inflation target under the

---

[2] Other currencies under the ERM II are pegged to the euro at central rates with a much larger band of ±15%. See details of the ERM II at http://www.ecb.int/press/key/date/1999/html/sp990918.en.html and at http://www.ecb.int/press/pr/date/2005/html/pr051128.en.html.

[3] See details of the "Five Economic Tests" at http://www.hm-treasury.gov.uk./documents/international_issues/the_euro/assessment/report/euro_assess03_repindex.cfm.

floating exchange rate regime possibly holds true in practice.[4] That is the policy is indeed independent and the Swedish krona is freely floating against all other currencies including the euro. Because there is no policy arrangement that prevents the krona and euro prices from diverging over time, it is likely that a cointegrating relationship between the two currencies is not present.

Whether or not the three EU currencies are cointegrated with the euro, and more importantly, whether or not the presence/absence of long-run equilibrium relationships implied by cointegration actually reflect differences in the degree of monetary interdependence and thus in the exchange rate regime with the EMU have not been jointly investigated by prior studies with post-EMU data. This investigation is of importance to EMU policymakers. According to the Maastricht Treaty, the monetary alignment or convergence is crucial because it ensures that price stability within the EMU area is maintained even with the inclusion of new member states.

The implications of the presence/absence of the cointegrating relationship are also of importance to foreign exchange market participants. The absence of cointegration and its error correction representation (Engel and Granger, 1987) implies that the price of one currency cannot be predicted by past prices of other currencies. This unpredictability is consistent with weak-form market efficiency. Conversely, however, the presence of cointegration and the predictability as a result of an error correction representation (which requires subsequent adjustments of cointegrated currency prices to retain a cointegrating relationship once deviation from the relationship occurs) may not necessarily imply market inefficiency. Baillie and Bollerslev (1989) interpret this predictability as *either* a violation of weak-form efficiency *or* evidence of a risk premium. Moreover, an error correction representation is not a risk-adjusted model, so the associated predictability may not truly represent arbitrage opportunities and/or the

[4] See further information on the Swedish monetary policy at http://www.riksbank.com.

ability of market participants to earn risk-adjusted excess returns (e.g., Dwyer and Wallace, 1992; Baffes, 1994; Engel, 1996; Masih and Masih, 2001; Ferre and Hall, 2002; Lence and Falk, 2005).

Because foreign exchange markets are global in scope and extremely large in scale, it is unlikely that the inefficiency exists simply as a result of policy coordination and especially over long-term horizons on which the cointegration theory is predicated. The relevant issue is whether or not the predictability associated with cointegration represents the risk premium which makes the forward exchange rate differ from the expected future spot exchange rate.[5] Prior studies using pre-EMU data have not shown that this is the case and to our knowledge no study has examined this issue using post-EMU data.

Given the niches in the literature regarding policy coordination, cointegration and the risk premium for major EU currencies and countries after the EMU inception, this study sets forth three main objectives. *First*, it examines whether or not the Danish krone, British pound and Swedish krona have long-run equilibrium or cointegrating relationships with the euro over the period from January 1999 through June 2006. *Second*, it investigates whether or not the presence/absence of the relationships is related to the degree of policy coordination, specifically monetary interdependence, and the differing exchange rate regime with the EMU. The Swiss franc and Japanese yen are also included in the analysis for comparative purposes because policy coordination between a non-EU country and the EMU is expected to be weak(er), intermittent or non-existent.[6] Further, because inflation is obviously related to or influenced by monetary policy actions, convergence of inflation rates should also be observed if spot exchange rate

---

[5] The predictability due to dynamic adjustments of cointegrated currency prices implies comovements of the currencies over time. These comovements can possibly represent a risk premium because investors obtain smaller diversification benefits (and hence incur higher risk) from holding a group of currencies including ones that are cointegrated.

[6] The U.S. dollar is not included because it is used as a numeraire for exchange rates.

cointegration truly reflects monetary interdependence. Thus, cointegration tests between the U.K., Danish and Swedish inflation rates and the EMU inflation rate are performed and inferences about long-run inflation convergence are obtained.[7] Conversely, deviation from a cointegrating relationship of spot exchange rates can represent transitory monetary independence rather than irrelevant equilibrium errors, if it is also directly linked with deviation from long-run convergence of inflation rates.[8] Whether or not the linkage exists is examined through reduced-form and structural VARs comprising the estimates of deviation from cointegrating relationships (i.e., cointegrating vectors or CIVs) for spot exchange rates and for inflation rates. *Third*, this study examines whether or not cointegration of spot exchange rates, if transpiring, represents a risk premium to foreign exchange market participants. This is done by examining the explanatory power of the CIV, which requires subsequent adjustments and comovements of cointegrated currency prices, for the return to forward speculation which is defined in Taylor (1995) as the difference between the future spot rate and the forward rate and which should have a zero mean in the absence of a risk premium.

The results indicate that spot exchange rates for the krone and the pound exhibit long-run equilibrium or cointegrating relationships with the euro while those others including the krona do not. Consistent with these results, the Danish and U.K. inflation rates show evidence of long-run convergence with the EMU inflation rate while the Swedish inflation rate shows evidence of divergence. Moreover, the CIV for spot exchange rates has explanatory power for the CIV for inflation rates in the reduced-form VAR. Consistently, an innovation or shock to the CIV for

---

[7] Specifically, cointegration of inflation rates can imply long-run inflation convergence if the coefficient estimates for a cointegrating relationship at least indicate that an increase in inflation in one country is associated with an increase in inflation in another country to maintain a long-run equilibrium. Westbrook (1998) and Trivez (2001), among others, also relate cointegration of inflation rates to convergence and monetary interdependence.

[8] The monetary independence must be transitory. Otherwise, the (*de facto*) fixed regime could not possibly be retained. In contrast, the floating regime implies monetary independence to achieve domestic objectives through time. This potentially explains why prior studies typically do not find evidence of cointegration among spot exchange rates of currencies under the floating regime.

spot exchange rates shows discernible short-term impacts on the CIV for inflation rates in the structural VAR. Both CIVs are also verified to be transitory, implying that monetary independence from the EMU can transpire only temporarily. Therefore, the presence of spot exchange rate cointegrating relationships indeed reflects the relatively stronger coordination of monetary policies and at least the *de facto* fixed exchange rate regime of Denmark and the U.K. with the EMU. Additionally, the presence of cointegration can represent the risk premium to foreign exchange market participants because the CIV for spot exchange rates can explain a statistically significant portion of the return to forward speculation.

The remainder of this study is organized as follows. Section 2 describes the data and explains the econometric methodology used, with estimation results and related findings set forth in Section 3. Section 4 provides conclusions.

2. Data and Methodology

The exchange rate data covering the period from January 1, 1999 (the first trading day for the EMU euro) to June 30, 2006 (the most recent trading day at the time of data collection) are obtained from the Datastream International databank. Specifically, spot and one-month forward exchange rates are daily and end-of-month observations, respectively, for the U.S. dollar prices of the Danish krone, British pound, Swedish krona, EMU euro, Swiss franc and Japanese yen. These exchange rates are transformed into natural logarithms for further analyses. Additionally, the consumer price index (CPI) data over the same period are obtained from the International

Financial Statistics (IFS) database. Inflation rates are then computed from the first differences of the CPIs in natural logarithms.[9]

To test for a cointegrating relationship of spot exchange rates, the Johansen cointegration procedure (e.g., Johansen, 1988) is used. The procedure is based on a VAR process in (1).[10]

$$X_t = \Phi_1 X_{t-1} + \ldots + \Phi_k X_{t-k} + \mu + \varepsilon_t \qquad (1)$$

where X_t is a *p*-dimensional vector of *p* variables; Φ_j are coefficient matrices; μ is a vector of constants; ε_t is a white noise error vector with non-diagonal covariance matrix Ω; and *k* is the minimum lag length that reduces serial correlation in residuals to zero statistically according to the Ljung-Box (L-B) *Q*-statistics.

The VAR in (1) can be transformed to its error correction representation in (2).

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-1} + \mu + \varepsilon_t \qquad (2)$$

where the matrix of interest is the long-run multiplier matrix $\Pi = \Phi(1) - I$. The Π matrix can be decomposed into two ($p \times r$) matrices such that $\alpha\beta' = \Pi$. The β matrix contains parameters for *r* cointegrating relationships (i.e., long-run equilibria) while the α matrix contains error correction coefficients which measure the extent to which each variable responds or adjusts to cointegrating vectors (CIVs) or deviation from the cointegrating relationships in a prior period.

---

[9] Daily, rather monthly, data for spot exchange rates are used to avoid a small(er) sample which can negatively affect the power of cointegration tests and the efficiency of parameter estimates. However, monthly data for CPIs must be used because daily data are not available. Further, monthly data for one-month forward exchange rates are used even if daily data are available. This is aimed to match the forecast interval with data periodicity and thus to avoid serial correlation in forecast errors when the relationship between spot and forward exchange rates is examined.

[10] Cointegration presupposes that variables in the system are non-stationary and integrated of the same order. Thus, the Dickey-Fuller (Dickey and Fuller, 1981) and Ng-Perron (Ng and Perron, 2001) unit root tests are performed. The results indicate that the exchange rate series are non-stationary and integrated of order one. Further, because the plots of exchange rate series show no upward or downward trends over the sample period, the deterministic specification for the VAR allows for a non-zero constant in the cointegration space but excludes deterministic trends in the levels of data. The unit root and no-deterministic-trend properties also hold true for inflation rate series. To conserve space, the unit root test results and plots of the series are not shown, but are available upon request.

The test statistic for the null hypothesis of at most r against the alternative of p cointegrating relationships is the λ_{trace} statistic given in (3).

$$\lambda_{\text{trace}} = -T \sum_{i=r+1}^{p} ln(1-\lambda_i) \tag{3}$$

where T is the number of observations and λ_i is an eigenvalue from maximum likelihood estimation (MLE) of (2).

If cointegration is detected, the exclusion test (Johansen, 1991) is performed to verify that currency j is truly essential to the cointegrating relationship(s). The relevant likelihood ratio test statistic, LR, with standard χ^2 inferences is under the null hypothesis that j can be excluded from the cointegrating relationship(s) and is given in (4).

$$\text{LR} = T \sum_{i=1}^{r} ln[(1-\lambda_i^*)/(1-\lambda_i)] \tag{4}$$

where λ_i^* is an eigenvalue from the restricted MLE under the null hypothesis.

Then, the weak exogeneity test (Johansen, 1992) is conducted. Weakly exogenous variables are the sources of common trends. Therefore, they do not respond to deviation from cointegrating relationships, but serve as attractors for the endogenous variables or those that adjust to the deviation. Testing the null hypothesis that currency j is weakly exogenous is done by restricting the row associated with j in the α matrix to zero. The test statistic takes the form of LR in (4) where λ_i^* is from the restricted MLE under the weak exogeneity null hypothesis. Whether or not the euro is weakly exogenous allows inferences about the possibility of the leadership role of EMU policies.

Convergence of inflation rates should also be detected if cointegration of the pertaining currencies with the euro truly represents the considerable degree of monetary interdependence and a *de facto* fixed exchange rate regime. Thus, cointegration tests are performed on the EMU inflation rate and the Danish, U.K. and Swedish inflation rates. Convergence implies that an increase (decrease) in the EMU inflation is associated with an increase (decrease) in non-EMU inflation to maintain a long-run equilibrium. Therefore, for inflation convergence to hold true, the beta coefficient estimate for the non-EMU inflation rate must be positive with respect to the EMU inflation rate.[11]

Next, because the CIV represents deviation from a cointegrating relationship, the reduced-form VAR is constructed to examine the linkages between two possible measures of transitory monetary independence as in (5) and (6).

$$\mathrm{CIVE}_t = a + \sum_{i=1}^{k} b_{t\text{-}i}\mathrm{CIVE}_{t\text{-}i} + \sum_{i=1}^{k} c_{t\text{-}i}\mathrm{CIVI}_{t\text{-}i} + \upsilon_{E,t} \qquad (5)$$

$$\mathrm{CIVI}_t = d + \sum_{i=1}^{k} e_{t\text{-}i}\mathrm{CIVE}_{t\text{-}i} + \sum_{i=1}^{k} f_{t\text{-}i}\mathrm{CIVI}_{t\text{-}i} + \upsilon_{I,t} \qquad (6)$$

where a and d are constant terms; CIVE and CIVI are the CIVs from the systems of exchange rates and inflation rates, respectively; and υ_E and υ_I are error terms.

Further, the linkages are examined through the impulse response functions which capture how an innovation or shock to one variable impacts another variable in a structural VAR model. Define the vector time series Z_t as $[\mathrm{CIVE}_t, \mathrm{CIVI}_t]'$ so that its structural moving average representation (MAR) can be expressed as in (7).

$$Z_t = A(L)\varepsilon_t \qquad (7)$$

where L is the lag operator, $A(\lambda) = \sum_{j=0}^{\infty} A_j\lambda^j$, $\varepsilon_t = [\varepsilon_{E,t}, \varepsilon_{I,t}]'$ and $E[\varepsilon_t\varepsilon_t'] = I$. The Wold representation theorem implies a reduced-form MAR for Z_t as in (8).

[11] Specifically, the cointegrating relationship takes the form $\beta_i\pi_i = \pi_{EMU}$ where $\beta_i > 0$; and π_i and π_{EMU} are inflation rates in country *i* and the EMU, respectively. Moreover, if β_i is positive but differs from unity, the convergence is of a weak form rather than a strong form in that inflation rates converge but do not differ from each other by only a constant mean in a long-run according to the relative PPP.

$$Z_t = C(L)\upsilon_t \tag{8}$$

where $E[\upsilon_t \upsilon_t'] = \Omega$ and the relationships between reduced-form and structural parameters are given by $\upsilon_t = A_0\varepsilon_t$ and $A_j = C_jA_0$.

Identification of the structural model from the reduced-form model is possible through restrictions on the A_0 matrix. Three distinct elements in Ω imply that three restrictions are already imposed on the four parameters in A_0. To "just identify" the structural model, one additional restriction is needed. This usually takes the form of a zero restriction on one the off-diagonal elements in A_0. For example, if it is assumed that CIVE is affected contemporaneously only by a (structural) shock to itself while CIVI is affected contemporaneously by both a shock to itself and a shock to CIVE, then A_0 becomes:

$$A_0 = \begin{bmatrix} a_{11} & 0 \\ a_{21} & a_{22} \end{bmatrix} \tag{9}$$

However, the monetary policy change is expected to impact currency prices more quickly than it does inflation rates due to short-run stickiness of general price levels (e.g., Wynne, 1995). Therefore, if CIVE captures the effect of a monetary policy shock before CIVI does, then the time lag exists and CIVI should not be impacted contemporaneously by the CIVE innovation (nor should CIVE be impacted contemporaneously by the CIVI innovation). In this case, the structural model is overidentified and A_0 becomes:

$$A_0 = \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} \tag{10}$$

which implies no correlation between reduced-form errors of CIVE and CIVI. For this specification of A_0 to be appropriate, the correlation between two reduced-form residuals from model estimation should be less than 0.2 in absolute values and the likelihood ratio test statistic should lead to non-rejection of the null hypothesis that overidentifying restrictions are not binding (Enders, 1995).

The remaining issue is whether or not cointegration of spot exchange rates can represent a risk premium to foreign exchange market participants. In absence of the risk premium, the forward rate unbiasedness hypothesis holds as in (11).

$$S_t = F_{t-1,t} + \varepsilon_t \qquad (11)$$

where S_t is the spot exchange rate at time t, $F_{t-1,t}$ is the forward exchange rate at time t-1 for maturity at time t and ε_t is a forecast error. However, with presence of the risk premium, (11) is modified to become:

$$S_t = F_{t-1,t} + \delta_t + \varepsilon_t \qquad (12)$$

where δ_t represents a time-varying risk premium. Further, (12) can be rearranged as:

$$S_t - F_{t-1,t} = \delta_t + \varepsilon_t \qquad (13)$$

where $S_t - F_{t-1,t}$ is the return to forward speculation.

Cointegration of spot exchange rates can represent the risk premium because deviation from a cointegrating relationship necessitates subsequent adjustments and comovements of cointegrated currency prices, thereby lowering diversification benefits (i.e., increasing the risk) for investors with exposure in various currencies. Thus, $CIVE_{t-1}$ or the last period's deviation from a cointegrating relationship of spot exchange rates is incorporated into (13) as a possible proxy for the risk premium. The resulting regression is estimated as:

$$S_t - F_{t-1,t} = a + b\,CIVE_{t-1} + \varepsilon_t \qquad (14)$$

where *a* and *b* are coefficients. For cointegration to possibly represent the risk premium, two conditions should be met. First, the return to forward speculation, $S_t - F_{t-1}$, is stationary so that it has a compatible time series property with CIVE which is, by definition, a stationary equilibrium error. Second and more importantly, $CIVE_{t-1}$ has explanatory power for S_t - F_{t-1} so that it explains away a significant portion of the return to forward speculation.[12]

3. Empirical Results

Table 1 presents results from bivariate cointegration tests between the U.S. dollar price of the euro (EE) and the U.S. dollar prices of the Danish krone (DK), British pound (BP), Swedish krona (SK), Swiss franc (SF) and Japanese yen (JY) in natural logarithms. The lag length *k* in the VAR is set equal to 2 for each pair of exchange rates. This lag length is appropriate because the L-B *Q*-statistics from the VAR estimation lead to non-rejection of the null hypothesis of no serial correlation in residuals (See Panel A). Next, the cointegration rank test results are presented in Panel B. The λ_{trace} statistics associated with the DK-EE and BP-EE pairs allow rejection of the null hypothesis of no cointegration (i.e., H_0: $r = 0$) at the 1% and 5% levels, respectively. In contrast, the λ_{trace} statistics associated with the SK-EE, SF-EE and JY-EE pairs are discernibly smaller and result in non-rejection of H_0: $r = 0$. Therefore, the rank tests suggest that only the pound and the krone are cointegrated with the euro. Conditional upon this finding, the cointegrating relationship estimates and the exclusion test results are shown in Panel C. For each cointegrated pair, the likelihood ratio test statistic (shown in the parenthesis) for the null hypothesis that the EE can be excluded from the cointegrating relationship is statistically significant at the 1% level. Thus, the euro is essential to each of the two cointegrating relationships, reiterating the rank test results that long-run equilibrium relationships between the krone and euro and between the pound and euro truly exist.

---

[12] The lagged return to forward speculation, S_{t-1} - $F_{t-2,t-1}$, can also be included in the right hand side of (14) to account for its role in explaining the current return to forward speculation, S_t - $F_{t-1,t}$. The explanatory power of the lagged return does not necessarily imply market inefficiency. Readers are referred to Hansen and Hodrick (1980), among others, for various possible reasons.

Table 2 summarizes cointegration findings between each currency and the euro as well as institutional arrangements between each country and the EMU area. The summary in Panel A suggests that being an EU member appears to be a "precursor" for a country's currency to be cointegrated with the euro. This parallels the fact that Switzerland and Japan are not EU countries and the finding that their currencies are not cointegrated with the euro. Further, although Denmark does not have a formal obligation to eventually join the EMU and adopt the euro (i.e., it has an opt-out option according to the Maastricht Treaty), the krone is obviously cointegrated with the euro as a result of the fixed regime through ERM II.

The summary in Panel A however reveals that *neither* ERM II *nor* an obligation to adopt the euro (i.e., no opt-out option) appears to be a "required" condition for spot exchange rate cointegration. Specifically, the U.K. is not part of the ERM II and it has an opt-out option, but its pound is still cointegrated with the euro. The cointegration evidence likely results from the U.K.'s willingness to consistently make its monetary policies and economic cycles compatible with the EMU area. In contrast, Sweden does not have an opt-out option and its krona is not cointegrated with the euro. It can essentially pursue independent monetary policies by not joining the ERM II (one of the Treaty's requirements prior to becoming an EMU member) and can practically postpone the EMU membership as long as it wishes.

Therefore, the required condition for spot exchange rate cointegration with the euro appears to be an EU country's willingness to make its policies, especially the monetary policy, become interdependent with the EMU. This can be achieved through transnational mandates (i.e., ERM II for Denmark) or domestically initiated mandates (i.e., the U.K's own policies to align its key economic variables with the EMU). Parallel evidence that this is likely true is shown in Panel B of Table 2. The U.K. and Danish inflation rates, as opposed to the Swedish inflation rate, are relatively more aligned with the EMU inflation rate over the 1996-2005 period. In fact, the Swedish inflation tends to be considerably lower than the EMU inflation, especially in 2004 and 2005. This implies that the Swedish monetary policy might have been stricter than, and thus independent from, the EMU monetary policy.[13]

In sum, Denmark and the U.K. have at least a *de facto* fixed exchange rate regime with the EMU. The coefficient estimate of 1.001 for the euro in the DK-EE relationship is very close to unity or practically unity if being rounded to two decimal places (See the first row in Panel C of Table 1). This estimate reaffirms that the krone is indeed subject to the fixed regime where it is pegged solely to the euro with a very narrow band through ERM II.[14] Although the coefficient estimate for the euro in the BP-EE relationship differs from unity, the pound is considered under a *de facto* fixed regime with the euro because a cointegrating relationship serves as a long-run equilibrium preventing the cointegrated variables from diverging from each other (See the second row in Panel C of Table 1).

To further verify that the krona is not cointegrated with the euro and to examine if the euro is weakly exogenous to the krone and the pound, a multivariate cointegration test of these four EU currencies is performed. The results are shown in Table 3. The VAR includes two lags because the L-B *Q*-statistics lead to non-rejection of the null hypothesis of no serial correlation in residuals (See Panel A). The rank test results indicate two cointegrating relationships among the four currencies (See Panel B). However, the exclusion test results clearly indicate that SK is not essential to the relationships because the test statistic of 0.39 leads to non-rejection of the

---

[13] A formal analysis of inflation convergence will be provided later in this Empirical Results section.

[14] Under a fixed regime where one currency is tied solely to another currency, the coefficient should be unity. Consider hypothetical Currency B which is pegged solely to hypothetical Currency A with some allowable fluctuation which has a zero mean. Thus, the "A" price of "B" can be expressed as $A/B = a + \varepsilon_1$ where a and ε_1 are constant and error terms, respectively. Then, take natural logarithms on both sides and incorporate Currency C as a numeraire to obtain $Ln(C/A) - Ln(C/B) = b + \varepsilon_2$ where b and ε_2 are also constant and error terms, respectively. Therefore, $Ln(C/A) = Ln(C/B) + b + \varepsilon_2$. That is the "C" price of "A" has a one-to-one relationship with the "C" price of "B" in natural logarithms.

excludability null hypothesis (See Panel C). This finding reiterates the bivariate test result in that the krona, while being an EU country's currency, is not cointegrated with the euro (nor with the krone and the pound).

Because SK is excludable, the VAR comprising only DK, BP and EE is estimated. The rank test results reveal two cointegrating relationships among the three currencies (See Panel D of Table 3). Further, the estimates of the relationships are re-parameterized such that bivariate relationships with the euro are obtained. These estimates (See Panel E of Table 3) are almost identical to the estimates directly derived from bivariate tests (See Panel C of Table 1). In fact, the coefficient estimate for the euro in the DK-EE relationship is 1.000 (*vis-à-vis* 1.001 from bivariate estimation) and is exactly equal to the theoretical magnitude to be expected under the fixed regime where the value of one currency is tied solely to another currency.[15]

The weak exogeneity test results are presented in Panel E of Table 3. Given the two cointegrating relationships among the three currencies, there must be only one common trend that drives the cointegrated currency prices in a long-run. Because the null hypothesis that DK, BP or EE is weakly exogenous can be soundly rejected, neither the krone nor the pound nor the euro is weakly exogenous such that it would solely represent the single common trend. Therefore, the common trend essentially comprises a combination of these three currencies. This result further implies that the EMU does not have the leadership role in determining monetary policy actions, specifically the exchange rate policy, for the U.K. and Denmark in a long-run. The policy is likely determined jointly through coordination and interactions among monetary authorities in the U.K., Denmark, and EMU over time.

---

[15] This improvement possibly results from incorporating additional cross-sectional information through a multivariate analysis.

To formally investigate inflation convergence, bivariate cointegration tests between the EMU inflation rate (IEMU) and the Danish, U.K., and Swedish inflation rates (IDM, IUK and ISK, respectively) are performed with results presented in Table 4.[16] The L-B *Q*-statistics in Panel A indicate that 12 lags are needed to eliminate serial correlation in residuals in the VAR. The rank test results in Panel B suggest that each of the three EU countries' inflation rates is cointegrated with the EMU inflation rate since H_0: $r = 0$ can be rejected at the 1% level. Most importantly, the cointegrating relationship estimates in Panel C appear to be consistent with the results from cointegration tests of spot exchange rates. Specifically, there is evidence of long-run inflation convergence for both IDM-IEMU and IUK-IEMU pairs because the coefficients for IDM and IUK are positive with respect to IEMU.[17] This convergence implies coordinative monetary polices and hence monetary interdependence that can retain a *de facto* fixed regime between the pound and euro and a fixed regime between the krone and euro. In contrast, there is evidence of divergence for the ISK-IEMU pair because the coefficient for ISK is negative with respect to IEMU. This divergence implies monetary independence to accomplish domestic objectives under a floating regime and is consistent with the absence of a cointegrating relationship between the krona and euro.

Table 5 shows results from the VAR comprising the estimates of deviation from cointegrating relationships of spot exchange rates and inflation rates for Denmark and the U.K. In the Denmark case, deviation from the cointegrating relationship of exchange rates (CIVDK) can be explained by its own past values ($CIVDK_{t-1}$ and $CIVDK_{t-3}$) at the 1% and 10% levels, respectively. (See Panel A). In particular, the coefficient estimate of 0.793 for $CIVDK_{t-1}$ is less

[16] Multivariate cointegration tests of inflation rates are not performed because, given limited monthly observations, the sample size would be severely small due to a large number of lags needed in the VAR to eliminate serial correlation in residuals.

[17] Thus, an increase (decrease) in the EMU inflation rate is associated with an increase (decrease) in the U.K. and Danish inflation rates in a long-run.

than unity. Therefore, deviation from a cointegrating relationship in a prior period is associated with a smaller magnitude of the deviation in the current period, indicating an adjustment towards maintaining a long-run equilibrium. Further, the lagged value of CIVDK (specifically, $CIVDK_{t-2}$) can significantly explain deviation from a cointegrating relationship of inflation rates (CIVIDM). This finding suggests that short-run divergence from a fixed krone/euro exchange rate (i.e., due to allowable fluctuation within a ±2.25% band) represents transitory monetary independence which results in temporary divergence from long-run convergence of the Danish and EMU inflation rates. In contrast, the lagged value of CIVIDM does not appear to explain CIVDK. This finding potentially results from short-run stickiness of general price levels which makes inflation respond to monetary policy changes less quickly than currency prices. Therefore, the explanatory power of CIVIDM for CIVDK is not present because currency prices have already captured the effects of monetary intervention.

Similar results are obtained in the U.K. case (See Panel B of Table 5). Deviation from the cointegrating relationship of spot exchange rates (CIVBP) can be explained by its own past values ($CIVBP_{t-1}$) at the 1% level. The coefficient estimate of 0.756 for $CIVBP_{t-1}$ suggests that the current period's deviation becomes smaller relative to the last period's deviation. Further, the lagged value of CIVBP (specifically, $CIVBP_{t-2}$) can explain deviation from a cointegrating relationship of inflation rates (CIVIUK) at the 5% level. Thus, short-run divergence from the *de facto* fixed regime between the pound and euro represents transitory monetary independence which results in temporary deviation from long-run convergence of the U.K. and EMU inflation rates. In sum, the linkages between CIVDK and CIVIDM and between CIVBP and CIVIUK imply that cointegrating relationships of spot exchange rates and short-run divergence from the relationships are meaningfully related to monetary policy interdependence and interactions between the two countries and the EMU.

Figure 1 shows plots of the impulse response functions (IRFs) from a structural VAR for CIVDK and CIVIDM. A_0 takes the form of a diagonal matrix because the correlation between reduced-form errors of -0.015 is obviously smaller than 0.20 in absolute values and because the likelihood ratio test statistic of 0.019 leads to non-rejection of the null hypothesis that the overidentifying restrictions are not binding. The resulting IRFs show that an innovation or shock to either CIVDK or CIVIDM affects itself only temporarily since the effects dissipate in subsequent months (See the first and the fourth graphs). This reaffirms that monetary independence between Denmark and the EMU can exist only temporarily. Second, the CIVDK innovation clearly impacts CIVIDM (See the second graph) while the CIVIDM innovation has very small effects on CIVDK (See the third graph) before eventually converging to zero. This implies that currency prices first absorb the effects of monetary policy shocks and then become the transmitter of the effects to inflation rates. This interpretation is also consistent with the price stickiness concept and with the reduced-form VAR results that the lagged value of CIVDK can explain CIVIDM but the lagged value of CIVIDM cannot explain CIVDK.

Figure 2 presents the IRF plots from a structural VAR for CIVBP and CIVIUK. A_0 also takes the form of a diagonal matrix since the correlation between reduced-form errors of -0.016 is smaller than 0.20 in absolute values and because the likelihood ratio test statistic of 0.021 for overidentifying restrictions is not statistically significant. The IRF patterns are similar to those for Denmark. Innovations in CIVBP and CIVIUK affect themselves and each other temporarily because the effects dissipate in subsequent months. More importantly, the CIVBP innovation clearly impacts CIVIUK (See the second graph) while the CIVIUK innovation has much smaller effects on CIVBP (See the third graph). Therefore, dynamic adjustments to mitigate deviation from a cointegrating relationship between the pound and euro do exist. Such deviation has a discernible linkage with transitory divergence of the U.K. and EMU inflation rates. Also consistent with the Denmark case, currency prices appear to be the transmitter of monetary effects to inflation rates.

The remaining issue is whether or not cointegration of spot exchange rates can represent a risk premium. As delineated earlier, two conditions should be met: 1) the return to forward speculation is stationary and 2) the lagged CIV of spot exchange rates has explanatory power for the return to forward speculation. Therefore, unit root tests of returns to forward speculation for the krone (DK_t - $FWDK_{t-1,t}$), pound (BP_t - $FWBP_{t-1,t}$), and euro (EE_t - $FWEE_{t-1,t}$) are performed. The results shown in Table 6 strongly indicate that each of the three series is stationary because the augmented Dickey-Full (ADF) unit root test statistic leads to rejection of the unit root null hypothesis at the 1% level. Therefore, the first condition is clearly satisfied.

Table 7 presents results from regressing the return to forward speculation on the lagged value of itself and/or the lagged CIV of spot exchange rates. The findings for the krone are shown in Panel A. the lagged return to forward speculation (DK_{t-1} - $FWDK_{t-2,t-1}$) can significantly explain the current return to forward speculation (DK_t - $FWDK_{t-1,t}$) at the 10% level (See the first row in Panel A). More importantly, $CIVDK_{t-1}$ which represents deviation from a cointegrating relationship between the krone and euro in a prior month also provides significant explanatory power for DK_t - $FWDK_{t-1,t}$. This holds true regardless of whether or not DK_{t-1} - $FWDK_{t-2,t-1}$ is included as an independent variable (See the second and third rows in Panel A)

The results for the krone are shown in Panel B of Table 7. Unlike the krone, the lagged return to forward speculation (BP_{t-1} - $FWBP_{t-2,t-1}$) does not appear to explain the current return to forward speculation (BP_{t-} - $FWBP_{t-1,t}$) (See the first row in Panel B). Nonetheless, the lagged value of CIV ($CIVBP_{t-1}$) which measures deviation from a cointegrating relationship between the pound and euro in a prior month can explain BP_{t-} - $FWBP_{t-1,t}$ at the 1% level. This holds true irrespective of whether or not $CIVBP_{t-1}$ is the only explanatory variable *or* an explanatory variable in addition to BP_{t-1} - $FWBP_{t-2,t-1}$ (See the second and third rows in Panel B).

Finally, the findings for the euro are presented in Panel C of Table 7. The lagged return to forward speculation for the euro (EE_{t-1} - $FWEE_{t-1,t-2}$), $CIVDK_{t-1}$ and $CIVBP_{t-1}$ can significantly explain the current return to forward speculation (EE_t - $FWEE_{t-1,t}$) on an individual basis (See the first three rows in Panel C). Further, it appears *at first* that these three variables do not explain EE_t - $FWEE_{t-1,t}$ on a collective basis (See the fourth row in Panel C). This is because none of the three is statistically significant if they are included together as explanatory variables. Since this result may be driven by multicollinearity, $CIVDK_{t-1}$ and $CIVBP_{t-1}$ are orthogonalized such that their relationships with other variables are removed and their orthogonalized values, $CIVDK_{ORT,t-1}$ and $CIVBP_{ORT,t-1}$, are used in the regression. The results then become clear that the return to forward speculation for the euro can be explained by the return in a prior month *and* by deviation from its cointegrating relationships with the krone and with the pound in a prior month (See the last row in Panel C).[18]

4. Conclusions

This study updates and extends prior studies related to policy coordination, cointegration, and the risk premium in foreign exchange markets. Specifically, it examines: (1) if spot exchange

[18] The results imply that cointegration of spot exchange rates is "one of the factors", rather than the "single factor", that can represent the risk premium. Despite the finding that the CIV is statistically significant, the magnitude of the $R^{2,}$ derived from the estimation, especially for the krone equation, implies that there are likely some other factors that can further explain away the return to forward speculation.

rates for the British pound, Danish krone, and Swedish krona have long-run equilibrium or cointegrating relationships with the euro after the inception of the EMU in January 1999; (2) if the presence/absence of the relationships actually reflects differing degrees of monetary interdependence of the U.K., Denmark, and Sweden with the EMU; and (3) if the relationships can represent the risk premium to foreign exchange market participants. These queries have not been jointly investigated nor answered by prior studies using pre- and/or post-EMU data.

The results suggest that the pound and the krone exhibit cointegrating relationships with the euro after the EMU inception. Further tests and supporting evidence indicate that these long-run relationships indeed reflect the relatively stronger degree of monetary interdependence and at least the *de facto* exchange rate regime of the U.K. and Denmark with the EMU. The krona is not cointegrated with the euro even though Sweden is an EU country. The absence of a long-run relationship between the two currencies mirrors the divergence between Swedish and EMU inflation rates and thus reaffirms the Swedish monetary independence and floating exchange rate regime. The Swiss franc and the Japanese yen, the currencies of non-EU countries, where policy coordination and monetary interdependence with the EMU are expectedly weak(er), intermittent and/or non-existent, are not cointegrated with the euro. Consistent with spot exchange rate cointegration, evidence of long-run convergence between the U.K. and Danish inflation rates and the EMU inflation rate is detected. Moreover, deviation from the spot exchange rate cointegrating relationship is verified to be transitory and has discernible linkages with deviation from long-run inflation convergence. Specifically, currency prices appear to be the transmitter of monetary effects on inflation rates.

Therefore, while being an EU country appears to be a pre-cursor to a long-run equilibrium relationship between its currency and the euro, the required condition for such relationship is its willingness to make the monetary policy strongly interdependent with the EMU through transnational mandates (i.e., ERM II for Denmark) or domestically initiated mandates (i.e., the U.K's own policies to align its key economic variables with the EMU). As a result, the pound is under a *de facto* fixed regime with the euro. The fact that the krone is under a fixed regime exclusively with the euro through ERM II is also confirmed. The magnitude of the cointegrating parameter is identical to the theoretical magnitude for the fixed regime where one currency is tied solely to another currency.

The above findings also imply that, based on monetary alignment or convergence, both Denmark and the U.K. are already informal EMU members. However, the two countries possibly realize greater benefits from retaining their national currencies and refraining from formal EMU membership. They can have some monetary independence at the present time (albeit small and transitory under the *de facto* fixed regime) and can pursue totally independent monetary policies in the future (if they elect to have a floating regime to achieve domestic objectives). They can also exert some influences on EMU monetary policies. This interpretation is supported by the weak exogeneity test results that the EMU does not have the leadership role in determining the exchange rate policy. Instead, the policy is likely determined jointly through interactions among monetary authorities in the U.K., Denmark, and EMU. These interactions and the floating regime possibility would not be possible if the two countries had joined the EMU since monetary policy implementations would be determined solely by the European Central Bank for the entire EMU area with one single common currency.

Additionally, the results indicate that deviation from cointegrating relationships between the pound and euro spot exchange rates and between the krone and euro spot exchange rates can explain a statistically significant portion of the return to forward speculation. Because this deviation requires dynamic adjustments of relevant currencies to maintain the relationships over time, the comovements emerge and foreign exchange market participants obtain smaller benefits and thus incur greater risk from having exposure in various currencies including the cointegrated ones. Therefore, cointegration of spot exchange rates can be considered one of the factors that represent the risk premium in foreign exchange markets, particularly for the three major EU currencies under investigation.

References

Baillie, R., Bollerslev, T., 1989. Common stochastic trends in a system of exchange rates. Journal of Finance 44, 167-181.

Baffes, J., 1994. Does comovement among exchange rates imply market inefficiency?. Economics Letters 44 (3), 273-280.

Crowder, W.J., 1996. The international convergence of inflation rates during fixed and floating exchange rate regimes. Journal of International Money and Finance 15, 551-575.

Dickey, D.A., Fuller, W.A., 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49, 1057-1072.

Dwyer, G.P. and Wallace, M.S., 1992. Cointegration and market efficiency. Journal of International Money and Finance 11, 318-327.

Enders, W., 1995. Applied Econometric Time Series. John Wiley & Sons, New York.

Engel, C., 1996. A note of cointegration and international capital market efficiency. Journal of International Money and Finance 15, 657-660.

Engle, R.F., Granger C.W.J., 1987. Co-integration and error correction: Representation, estimation, and testing. Econometrica 55, 251-276.

Ferre, M., Hall, S.G., 2002. Foreign exchange market efficiency and cointegration. Applied Financial Economics 12 (2), 131-139.

Gonzalo, J., Granger C.W.J., 1995. Estimation of common long-memory components in cointegrated system. Journal of Business and Economic Statistics 13, 27-35.

Hansen, L.P., Hodrick, R.J., 1980. Forward exchange rates as optimal predictors of future spot rates: An econometric analysis. Journal of Political Economy 88, 829-853.

Haug, A.A., Mackinnon, J.G., Michelis, L., 2000. European Union: A Cointegration analysis. Journal of International Money and Finance 19, 419-432.

Johansen, S., 1988. Statistical analysis of cointegrating vectors. Journal of Economic Dynamics and Control 12, 231-254.

Johansen, S., 1991. Estimation and hypothesis testing of cointegrating vectors in Gaussian vector autoregressive models. Econometrica 59, 1551-1580.

Johansen, S., 1992. Testing weak exogeneity and the order of cointegration in UK money demand data. Journal of Policy Modeling 14, 313-334.

Johansen, S., 1995. Likelihood-based Inference in Cointegrating Vector Autoregressive Models. Oxford University Press, Oxford, UK.

Lajaunie, J., Naka, A., 1992. Is the Tokyo spot foreign exchange market consistent with the efficient market hypothesis? Review of Financial Economics 2, 68-74.

Lence, S., Falk, B., 2005. Cointegration, market integration, and market efficiency. Journal of International Money and Finance 24, 873-890.

MacDonald, R., Taylor M.P., 1989. Foreign exchange market efficiency and cointegration: Some evidence from the recent float. Economics Letters 29 (1), 63-68.

MacKinnon, J.G., 1996. Numerical distribution functions for unit root and cointegration tests. Journal of Applied Econometrics 11 (6), 601-618.

Masih, R., Masih, A.M.M., 2001. Long and short term dynamic causal transmission amongst international stock markets. Journal of International Money and Finance 20, 563-587.

Ng, S., Perron P., 2001. Lag Length selection and the construction of the unit root tests with good size and power. Econometrica 69, 1519-1554.

Rangvid, J., Sorensen, C., 2002. Convergence in the ERM and declining numbers of common stochastic trends. Journal of Emerging Market Finance 1 (2), 183-213.

Rapp, T.A., Sharma, S.C., 1999. Exchange rate market efficiency: Across and within countries. Journal of Economics and Business 51 (5), 423-439.

Taylor, M.P., 1995. The economics of exchange rates. Journal of Economic Literature 33, 13-47.

Trivez, F.J., 2001. Analysis of the Long-term Relationships of the Underlying Rates of Inflation in the EMU Member States. Applied Financial Economics 33, 2001-2007.

Westbrook, J.A., 1998. Monetary Integration, Inflation Convergence and Output Shocks in the European Monetary System. Economic Inquiry 36(1), 138-144.

Wynne, M.A., 1995. Sticky prices: What is the evidence? Federal Reserve Bank of Dallas Economic Review, First Quarter, 1-12.

Table 1: Bivariate Cointegration Tests of Spot Exchange Rates

Panel A: Lag Length Selection[a]

Danish Krone (DK) - EMU Euro (EE)		**British Pound (BP) - EE**		**Swedish Krona (SK) - EE**		**Swiss Franc (SF) - EE**		**Japanese Yen (JY) - EE**	
Equation	**$k = 2$**	**Equation**	**$k = 2$**	**Equation**	**$k = 2$**	**Equation**	**$k = 2$**	**Equation**	**$k = 2$**
DK	6.905	BP	14.978	SK	13.216	SF	17.406	JY	7.201
EE	7.162	EE	6.741	EE	7.145	EE	7.010	EE	7.151

Panel B: Cointegration Rank[b]

H_0:	**λ_{trace}**				
	DK - EE	**BP - EE**	**SK - EE**	**SF - EE**	**JY - EE**
$r = 0$	21.25**	26.70***	8.86	16.46	8.46
$r \leq 1$	0.71	1.26	0.82	2.37	0.81

Panel C: Cointegrating Relationship Estimate[c]

Exchange Rate Pair	**Estimate**			
DK - EE	1.000DK	=	1.001EE (19.83***)	-2.007
BP - EE	1.000BP	=	0.681EE (23.81***)	+0.446

Note: [a] All exchange rates are the U.S. dollar prices of respective currencies in natural logarithms. The VAR is estimated based on the deterministic specification that a constant is present in the cointegration space. k is the number of lags included. The numbers shown are the L-B Q-statistics which are calculated from each equation in the VAR and distributed as $\chi^2(12)$ under the null hypothesis of no serial correlation in residuals.

[b] Based on the VAR with $k = 2$, the λ_{trace} statistics are compared against critical values tabulated in Johansen (1995). The 10% critical value for H_0: $r = 0$ is 17.79.

[c] The cointegrating relationship is normalized by either DK or BP. Numbers in parentheses are the likelihood ratio test statistics which are distributed as $\chi^2(1)$ under the null hypothesis that EE can be excluded from the cointegrating relationship.

*** and ** indicate rejection of the null hypothesis at the 1% and 5% levels, respectively.

Table 2: Summary of Cointegration Findings, Institutional Arrangements, and Inflation Rates

Panel A: Summary of Cointegration Findings and Institutional Arrangements

Aspect	Denmark	U.K.	Sweden	Switzerland	Japan
Cointegration of its Currency with Euro?	Yes	Yes	No	No	No
EU Member?	Yes	Yes	Yes	No	No
Part of ERM II?	Yes	No	No	No	No
Formal Obligation to Join EMU?	No	No	Yes	N/A	N/A

Panel B: Annual Inflation Rate (%)

Year	Denmark	U.K.	Sweden	EMU
1996	2.111	2.449	0.533	2.145
1997	2.196	3.132	0.659	1.575
1998	1.853	3.418	-0.267	1.091
1999	2.479	1.555	0.462	1.120
2000	2.925	2.927	0.898	2.335
2001	2.350	1.821	2.408	2.110
2002	2.426	1.634	2.157	2.250
2003	2.091	2.914	1.928	2.073
2004	1.160	2.964	0.370	2.140
2005	1.809	2.830	0.455	2.191

Note: The data in Panel B are from the International Financial Statistics database.

Table 3: Multivariate Cointegration Tests of EU Spot Exchange Rates

Panel A: Lag Length Selection[a]

Equation	$k = 2$
DK	6.728
BP	15.022
SK	13.954
EE	6.868

Panel B: Cointegration Rank[b]

H_0:	λ_{trace}
$r = 0$	62.42***
$r \leq 1$	31.98*
$r \leq 2$	9.70
$r \leq 3$	1.56

Panel C: Exclusion Test[c]

DK	BP	SK	EE
16.18***	20.80***	0.39	16.51***

Panel D: Cointegration Rank (without SK)[d]

H_0:	λ_{trace}
$r = 0$	51.13***
$r \leq 1$	21.35**
$r \leq 2$	1.57

Panel E: Cointegrating Relationship Estimate[e]

Estimate			
1.000DK	=	1.000EE	-2.007
		(373.078***)	
1.000BP	=	0.678EE	+0.446
		(20.804***)	

Panel F: Weak Exogeneity Test[f]

DK	BP	EE
6.70**	22.25***	7.04**

Note: [a] The VAR is estimated based on the deterministic specification that a constant is present in the cointegration space. k is the number of lags included. The numbers shown are the L-B Q-statistics which are calculated from each equation in the VAR and distributed as $\chi^2(12)$ under the null hypothesis of no serial correlation in residuals.
[b] Based on the VAR with $k = 2$, the λ_{trace} statistics are compared against critical values tabulated in Johansen (1995). The 10% critical values are 49.91 and 31.88 for H_0: $r = 0$ and H_0: $r \leq 1$, respectively.

[c] Conditional on the presence of two cointegrating relationships, the numbers shown are the likelihood ratio test statistics which are distributed as $\chi^2(2)$ and under the null hypothesis that the exchange rate *i* can be excluded from the relationships.
[d] Based on the VAR with $k = 2$, the λ_{trace} statistics are compared against critical values tabulated in Johansen (1995). The 10% critical values are 31.88 and 17.79 for H_0: $r = 0$ and H_0: $r \leq 1$, respectively.
[e] Cointegrating relationships are normalized by either DK or BP and the coefficients are re-parameterized such that each bivariate relationship with EE is obtained. Numbers in parentheses are the asymptotically valid *t*-statistics under the null hypothesis that EE can be excluded from the cointegrating relationship.
[f] Conditional on the presence of two cointegrating relationships, the numbers shown are the likelihood ratio test statistics which are distributed as $\chi^2(2)$ under the null hypothesis that the exchange rate *i* is weakly exogenous and hence is the source of common trends.

***, ** and * indicate rejection of the null hypothesis at the 1%, 5% and 10% levels, respectively.

Table 4: Bivariate Cointegration Tests of EU Inflation Rates

Panel A: Lag Length Selection[a]

Danish Inflation Rate (IDM) - EMU Inflation Rate (IEMU)		**U.K. Inflation Rate (IUK) - IEMU**		**Swedish Inflation Rate (ISW) - IEMU**	
Equation	$k = 12$	**Equation**	$k = 12$	**Equation**	$k = 12$
IDM	14.857	IUK	17.096	ISW	11.610
IEMU	9.887	IEMU	6.721	IEMU	11.893

Panel B: Cointegration Rank[b]

H_0:	λ_{trace}		
	IDM - IEMU	**IUK - IEMU**	**ISW - IEMU**
$r = 0$	26.35***	25.34***	26.65***
$r \leq 1$	5.68	2.59	5.87

Panel C: Cointegrating Relationship Estimate[c]

Inflation Rate Pair	**Estimate**
IDM - IEMU	0.073IDM = 1.000IEMU –0.172 (14.92***)
IUK - IEMU	0.057IUK = 1.000IEMU –0.174 (19.87***)
ISW - IEMU	-0.008ISW = 1.000IEMU –0.183 (14.61***)

Note: [a] The VAR is estimated based on the deterministic specification that a constant is present in the cointegration space. k is the number of lags included. The numbers shown are the L-B Q-statistics which are calculated from each equation in the VAR and distributed as $\chi^2(12)$ under the null hypothesis of no serial correlation in residuals.

[b] Based on the VAR with $k = 12$, the λ_{trace} statistics are compared against critical values tabulated in Johansen (1995). The 10% critical value for H_0: $r = 0$ is 17.79.

[c] For comparative purposes, the cointegrating relationship is normalized by the EMU inflation rate. Numbers in parentheses are the likelihood ratio test statistics which are distributed as $\chi^2(1)$ under the null hypothesis that IEMU can be excluded from the cointegrating relationship.

*** indicates rejection of the null hypothesis at the 1% level.

Table 5: Relationship between CIVs of Spot Exchange Rates and Inflation Rates

Panel A: Denmark[a]

Dependent Variable	Independent Variables:					
	$CIVDK_{t-1}$	$CIVDK_{t-2}$	$CIVDK_{t-3}$	$CIVIDM_{t-1}$	$CIVIDM_{t-2}$	$CIVIDM_{t-3}$
$CIVDK_t$	0.793	-0.086	0.200	-0.001	-0.001	0.0004
	(7.304***)	(-0.625)	(1.807*)	(-1.313)	(-1.612)	(0.999)
$CIVIDM_t$	-30.209	63.347	-10.122	-0.027	-0.182	-0.233
	(-1.126)	(1.872*)	(-0.370)	(-0.245)	(-1.717*)	(-2.113**)
$\chi^2(16) =$ 21.599						

Panel B: U.K. [b]

Dependent Variable	Independent Variables:					
	$CIVBP_{t-1}$	$CIVBP_{t-2}$	$CIVBP_{t-3}$	$CIVIUK_{t-1}$	$CIVIUK_{t-2}$	$CIVIUK_{t-3}$
$CIVBP_t$	0.756	-0.013	0.036	-0.015	0.011	0.001
	(6.776***)	(-0.094)	(0.333)	(-1.562)	(1.094)	(0.136)
$CIVIUK_t$	0.816	-3.259	1.807	0.045	-0.148	-0.256
	(0.662)	(-2.115**)	(1.503)	(0.419)	(-1.384)	(-2.325**)
$\chi^2(16) =$ 22.772						

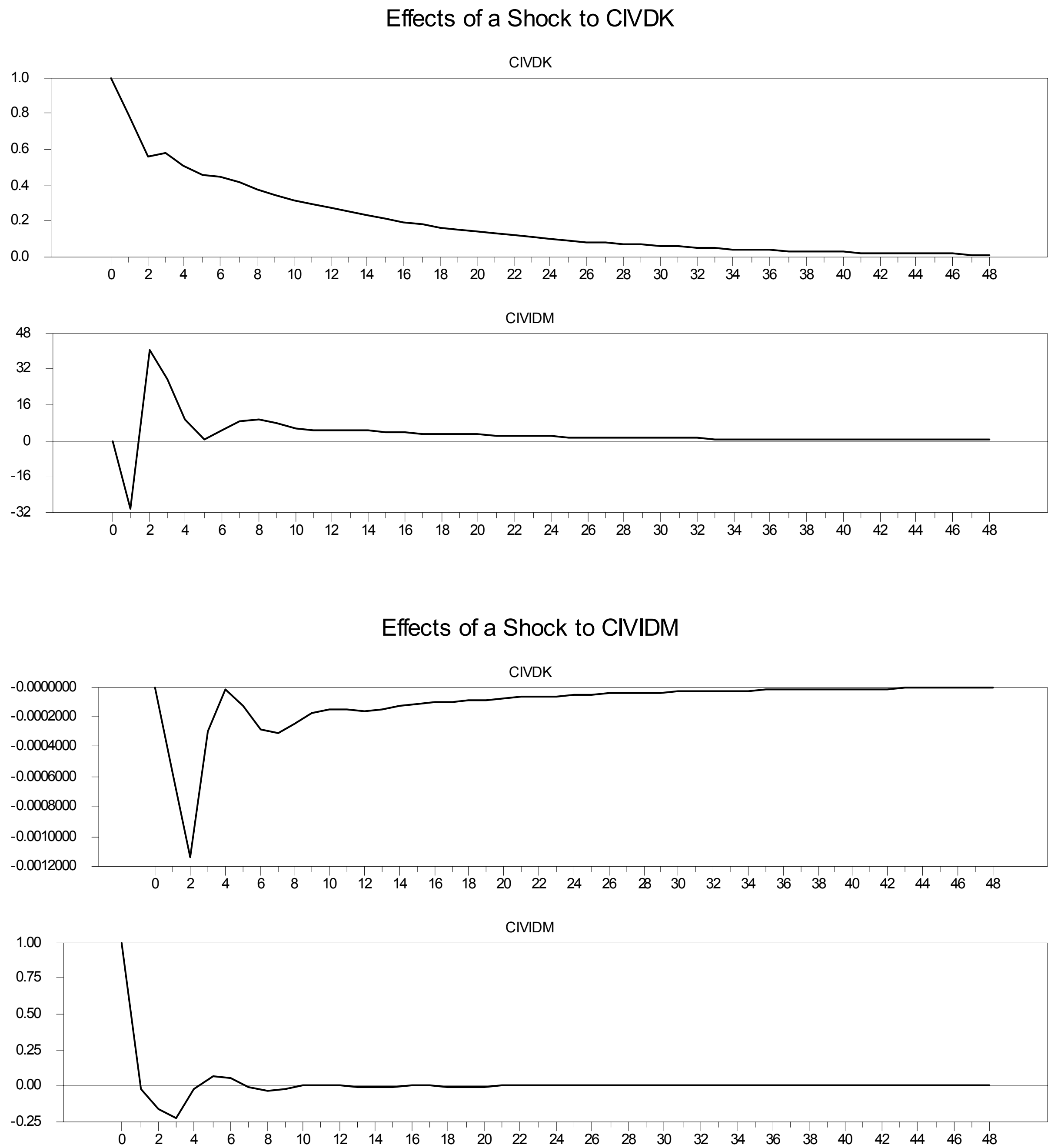
Note: [a] CIVDK is the cointegrating vector (CIV) or deviation from the cointegrating relationship between the Danish krone and European euro and can be expressed as 1.000DK -1.000EE +2.007 (See Table 3). CIVIDM is the CIV or deviation from the cointegrating relationship between Danish and EMU inflation rates and can be expressed as 0.073IDM -1.000IEMU +0.172 (See Table 4).

[b] CIVBP is the cointegrating vector (CIV) or deviation from the cointegrating relationship between the British pound and European euro and can be expressed as 1.000BP -0.678EE -0.446 (See Table 3). CIVIUK is the CIV or deviation from the cointegrating relationship between U.K. and EMU inflation rates and can be expressed as 0.057IUK -1.000IEMU +0.174 (See Table 4).

$\chi^2(16)$ is the test statistic for the Portmanteau test for joint serial correlation. The lag length chosen (k = 3) for the VAR allows non-rejection of the null hypothesis of joint serial correlation at the 10% level. Numbers outside the parentheses are the coefficient estimates while those inside the parentheses are the *t*-statistics.

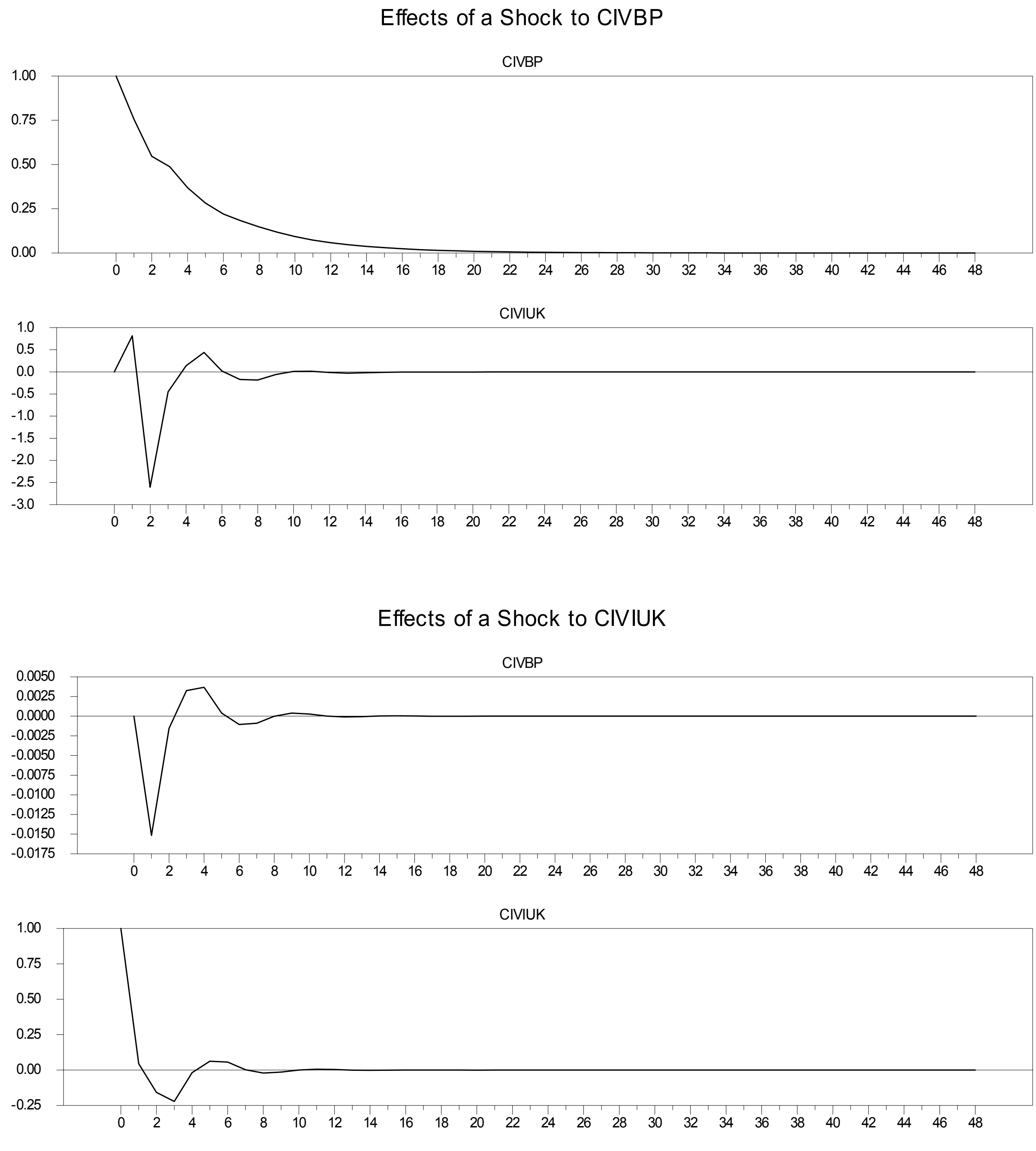
***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Figure 1: Impulse Response Analysis of CIVDK and CIVIDM



Note: The correlation between reduced-form residuals of CIVDK and CIVIDM is -0.015. The likelihood ratio test statistic for overidentifying restrictions is $\chi^2(1) = 0.019$. The impulse response functions are based on a diagonal matrix A_0 as in Equation (10).

Figure 2: Impulse Response Analysis of CIVBP and CIVIUK



Note: The correlation between reduced-form residuals of CIVBP and CIVIUK is -0.016. The likelihood ratio test statistic for overidentifying restrictions is $\chi^2(1) = 0.021$. The impulse response functions are based on a diagonal matrix A_0 as in Equation (10).

Table 6: Unit Root Test of the Return to Forward Speculation

Return to Forward Speculation	ADF Unit Root Test Statistic	*k*	$\chi^2(12)$
DK_t - $FWDK_{t-1,t}$	-7.671***	0	7.825
BP_t - $FWBP_{t-1,t}$	-4.553***	2	15.731
EE_t - $FWEE_{t-1,t}$	-7.710***	0	8.315

Note: DK_t is the spot U.S. dollar/Danish krone exchange rate at (the end of month) t while $FWDK_{t-1,t}$ is the forward U.S. dollar/Danish krone exchange rate determined at (the end of month) t-1 for delivery at (the end of month) t. BP_t is the spot U.S. dollar/British pound exchange rate at t while $FWBP_{t-1,t}$ is the forward U.S./British pound exchange rate determined at t-1 for delivery at t. EE_t is the spot U.S. dollar/EMU euro exchange rate at t while $FWEE_{t-1,t}$ is the forward U.S. dollar/EMU euro exchange rate determined at t-1 for delivery at t. The augmented Dickey-Fuller (ADF) unit root test statistic is under the null hypothesis that the series contains a unit root. The critical value from MacKinnon (1996) is -3.430. Further, $\chi^2(12)$ is the L-B *Q*-statistic under the null hypothesis of no serial correlation in residuals. The chosen lag length *k* allows non-rejection of this null hypothesis at the 5% level.

*** indicates rejection of the null hypothesis at the 1% level.

Table 7: Relationship between Return to Forward Speculation and CIV of Spot Exchange Rates

Panel A: Danish Krone

Dependent Variable	Independent Variables:			R^2
	Constant	DK_{t-1} - $FWDK_{t-2,t-1}$	$CIVDK_{t-1}$	
DK_t - $FWDK_{t-1,t}$	0.001	0.205		0.043
	(0.454)	(1.964*)		
	0.001		2.932	0.038
	(0.202)		(1.845*)	
	0.001	0.186	2.718	0.076
	(0.288)	(1.794*)	(1.732*)	

Panel B: British Pound

Dependent Variable	Independent Variables:			R^2
	Constant	BP_{t-1} - $FWBP_{t-2,t-1}$	$CIVBP_{t-1}$	
BP_t - $FWBP_{t-1,t}$	0.003	-0.053		0.003
	(1.193)	(-0.504)		
	0.002		0.276	0.178
	(0.810)		(4.339***)	
	0.002	-0.071	0.299	0.209
	(1.095)	(-0.735)	(4.709***)	

Panel C: EMU Euro

Dependent Variable	Independent Variables:						R^2
	Constant	EE_{t-1} - $FWEE_{t-2,t-1}$	$CIVDK_{t-1}$	$CIVBP_{t-1}$	$CIVDK_{ORT,t-1}$	$CIVBP_{ORT,t-1}$	
EE_t - $FWEE_{t-1,t}$	0.001	0.201					0.041
	(0.417)	(1.922*)					
	0.001		3.097				0.041
	(0.204)		(1.938*)				
	0.0004			0.172			0.046
	(0.143)			(2.055**)			
	0.001	0.134	2.445	0.133			0.102
	(0.203)	(1.243)	(1.530)	(1.488)			
	0.001	0.201			3.038	0.166	0.102
	(0.426)	(1.963*)			(1.863*)	(1.828*)	

Note: DK_t - $FWDK_{t-1,t}$, BP_t - $FWBP_{t-1,t}$ and EE_t - $FWEE_{t-1,t}$ are returns to forward speculation as in Table 6. DK_{t-1}- $FWDK_{t-2,t-1}$, BP_{t-1} - $FWBP_{t-2,t-1}$, and EE_{t-1} - $FWEE_{t-2,t-1}$ are the lagged returns to forward speculation. CIVDK and CIVBP are the CIVs or deviation from spot exchange rate cointegrating relationships defined in Note to Table 5. The subscript "ORT" indicates that the variable is orthogonalized by other independent variables in the equation to mitigate multicollinearity. Numbers outside the parentheses are the coefficient estimates while those inside the parentheses are the *t*-statistics.

***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.