Chaos, Solitons and Fractals 86 (2016) 92–100

Contents lists available at ScienceDirect

Chaos, Solitons and Fractals

Nonlinear Science, and Nonequilibrium and Complex Phenomena

journal homepage: www.elsevier.com/locate/chaos

Long-memory exchange rate dynamics in the euro era

John T. Barkoulas*, Anthony G. Barilla, William Wells

Department of Finance and Economics, Georgia Southern University, Statesboro, GA 30460 USA

ARTICLE INFO

Article history:
Received 2 October 2015
Accepted 8 February 2016

Keywords:
Long memory
Cointegration
Exchange rates

ABSTRACT

We investigate the long-run dynamics of a system of eight major exchange rates in the euro era using both integer and fractional cointegration methodologies. Contrary to the fragile evidence in the pre-euro era, robust evidence of linear cointegratedness is obtained in the foreign exchange market during the euro era. Upon closer examination, deviations from the cointegrating relationship exhibit nonstationary, long-memory dynamic behavior (Joseph effect). We find the long-memory evidence to be temporally stable in the most recent era. Finally, the foreign exchange system dynamics appears to be characterized by less persistence (smaller fractional exponent) in the euro era (as compared to pre-euro time periods), potentially indicating increased policy coordination by central banks in the recent period.

1. Introduction

Cointegration methodology has been extensively used as a convenient way of testing for the weak form of asset market efficiency, which states that no asset price should be forecastable from the prices of other assets. The rationale derives from the Granger representation theorem [8] which, applied to a system of asset prices, states that the presence of cointegration in the system directly implies the existence of Granger-causal orderings among the cointegrated asset prices. Such orderings enable one to predict one asset price on the basis of the others, which contradicts the weak-form market efficiency hypothesis.[1]

Hakkio and Rush [11], Baillie and Bollerslev [2], Crowder [5], and Lopez [15], inter alia, find cointegration in systems of spot exchange rates, which would seem to contradict foreign exchange market efficiency.[2] Sephton and Larsen [22], Diebold et al. [7], and Barkoulas and Baum [4] describe the evidence of cointegrated systems among foreign exchange rates as fragile with respect to temporal stability, out-of-sample forecasting effectiveness, and model specification. However, Baillie and Bollerslev [3] provide strong evidence that foreign exchange rates form a fractionally cointegrated system, that is, deviations from a presumed long-run relationship are a long-memory process. More specifically, the disequilibrium error is an integrated process of estimated order $I(0.89)$ thus exhibiting nonstationary but mean-reverting dynamics. Such a finding suggests that dynamic adjustments to the long-run attracting set are slow to complete and potentially forecastable.[3]

In this paper, we examine the cointegratedness among foreign exchange rates in the post-1999 period, that is, in the euro era, unlike previous studies that focus on time periods prior to the introduction of the euro. Analyzing

* Corresponding author. Tel.: +1 912 4781838; fax. +1 912 4780710.
E-mail addresses: jbarkoul@georgiasouthern.edu (J.T. Barkoulas), barilla@georgiasouthern.edu (A.G. Barilla), wwells@georgiasouthern.edu (W. Wells).

[1] See Fama [9] for a discussion of the various forms of market efficiency.

[2] Sephton [21] finds evidence of nonlinear cointegration in a system of four major currencies. Lopez [15] examines the cointegration evidence across regime shifts in central bank behavior over the period 01/04/1974–12/31/1991.

[3] A time series y_t is said to be integrated of order d, denoted by $I(d)$, if it has to be differenced d times to render it covariance stationary.

http://dx.doi.org/10.1016/j.chaos.2016.02.007

the long-run foreign exchange dynamics in the most recent era would enable a reassessment of the nature and stability of its underlying laws of change and provide useful comparisons to the evidence obtained in the pre-euro era. Long memory or strong persistence captures data dependence which is based on the exact temporal order of events, referred to as the Joseph effect by Mandelbrot and Wallis [16].[4] It is characterized by aperiodic cyclical behavior or almost cycles, that is, stretches (waves) which occur without any regularity in either time of occurrence or its duration. The consequences of a shock to the system are sustainable declining at a hyperbolic rate until they dissipate asymptotically. Thus there is statistical dependence even between remote observations implying the possibility of increased longer-term forecastibility. We consider both integer and fractional orders of integration in the long-run relationship in foreign exchange rates. Using the Johansen cointegration method, we find robust evidence of an integer-order linear long-run equilibrium relationship in the system of foreign currency spot rates, which is contrary to the fragile and contradictory evidence obtained in the pre-euro era. Upon closer examination, the evidence suggests that the dynamic structure of the contegrating relationship exhibits nonstationary mean-reverting behavior with long-memory features, which is temporally stable. The average estimate for the fractional exponent in the disequilibrium error process is less than that observed in the pre-euro era, thus suggesting less persistence over the most recent period. This may be indicative of increased coordination (explicit or implicit) of policies and foreign exchange market interventions by the central banks since the introduction of the euro.

The remainder of the paper is constructed as follows. Section 2 presents the econometric methodologies employed. Section 3 discusses the data and empirical results. A summary of our findings concludes the paper in Section 4.

2. Econometric methodologies

We first describe the Johansen cointegration method which allows for integer orders of integration followed by the fractional-differencing estimation method.

2.1. The Johansen cointegration method

We employ the Johansen cointegration method [12, 13] to determine the existence of common trends in a system of currency spot rates in the euro era.

Without any loss of generality, a $p-$ dimensional vector autoregressive (VAR) process of $k-$ th order can be written as follows

$$\Delta X_t = \mu + \Theta_1 \Delta X_{t-1} + \ldots + \Theta_{k-1} \Delta X_{t-k-1} + \Pi X_{t-k} + \varepsilon_t \quad (1)$$

where Δ is the first-difference lag operator, X_t is a $(p \times 1)$ random vector of time series variables with order of integration of at most one, denoted by $I(1)$, μ is a $(p \times 1)$ matrix of constants, ε_t is a sequence of zero-mean $p-$dimensional white noise vectors, Θ_i are $(p \times p)$ matrices of parameters, and Π is a $(p \times p)$ matrix of parameters the rank of which contains information about long-run relationships among the variables in the VAR.

Expression (1) is referred to as the vector error correction model (VECM). If Π has full rank p, all elements in X_t are stationary. If the rank of Π is zero, the model reduces to a VAR in first-differences. The interesting case occurs when $0 < r < p$, which suggests the existence of r cointegrating relationships. In this case there exist $(p \times r)$ matrices α and β such that $\Pi = \alpha\beta'$. β is the matrix of cointegrating vectors and has the property that $\beta' X_t$ is stationary even though X_t may be individually $I(1)$ processes.

To test the hypothesis that the number of cointegrating vectors is at most r, the trace statistic is calculated

$$tr(r) = -T \sum_{i=r+1}^{p} ln\left(1 - \hat{\lambda}_i\right), \quad (2)$$

where $\hat{\lambda}_{r+1}, \ldots, \hat{\lambda}_p$ are the $(p-r)$ smallest eigenvalues to the generalized eigenvalue problem

$$\left| \lambda S_{kk} - S_{k0} S_{00}^{-1} S_{0k} \right| = 0. \quad (3)$$

The S_{ij} are residual moment matrices from the VECM in (1). The asymptotic distribution for the trace test statistic is non-standard and depends only on $(p-r)$. Critical values obtained from Monte Carlo simulations of the limiting distribution are given in Johansen and Juselius [13] and Osterwald-Lenum [17]. To account for finite-sample bias, we follow Reinsel and Ahn [19] and Reimers [18] in correcting the trace test statistics by multiplying them by the scale factor $T - pk/T$.

2.2. Fractionally differenced modeling

The model of an autoregressive fractionally integrated moving average process of order (p, d, q), denoted by ARFIMA(p, d, q), with mean μ, may be written using operator notation as

$$\Phi(L)(1-L)^d (y_t - \mu) = \Theta(L) u_t, u_t \sim i.i.d.\left(0, \ \sigma_u^2\right) \quad (4)$$

where L is the backward-shift operator, $\Phi(L) = 1 - \phi_1 L - \ldots - \phi_p L^p$, $\Theta(L) = 1 + \vartheta_1 L + \ldots + \vartheta_p L^p$, and $(1-L)^d$ is the fractional differencing operator. The parameter d is allowed to assume any real value. The arbitrary restriction of d to integer values gives rise to the standard autoregressive integrated moving average (ARIMA) model. The stochastic process y_t is both stationary and invertible if all roots of $\Phi(L)$ and $\Theta(L)$ lie outside the unit circle and $|d| < 0.5$. The process is said to exhibit long-memory behavior for $d \in (0, 1)$. For $d \in [0.5, 1)$, y_t is nonstationary (having an infinite variance) but it is mean reverting.

Robinson [20] proposes a Gaussian semiparametric estimator, GS hereafter, of the self-similarity parameter H. Assume that the spectral density of the time series, denoted by $f(.)$, behaves as

$$f(\xi) G \xi^{(1-2H)} \text{as}\, \xi \to 0^+ \quad (5)$$

for $G \in (0, \infty)$ and $H \in (0, 1)$. The self-similarity parameter H relates to the long-memory parameter d by

[4] Named after the biblical story based on Joseph's prophecy of seven years of prosperity to be followed by seven years of famine.