Surveying the validity of PPP in the dairy sector of EU by using nonlinear cointegration

Zafeiriou Eleni[1], Koutroumanidis Theodoros[2], Karelakis Christos[3], Koutroubas Spyridon[4]

[1] Lecturer, Department of Agricultural Development, Democritus University of Thrace
ezafir@agro.duth.gr
[2] Professor, Department of Agricultural Development, Democritus University of Thrace
tkoutrou@agro.duth.gr
[3] Lecturer, Department of Agricultural Development, Democritus University of Thrace
chkarel@agro.duth.gr
[4] Professor, Department of Agricultural Development, Democritus University of Thrace
skoutrou@agro.duth.gr

Abstract. The present study surveys the validity of PPP in the dairy sector for European countries. We implement in the context of nonlinear smooth transmition error correction model the associated nonlinear ECM-based tests as well as the nonlinear analogue of the residual-based test for cointegration in linear models proposed by Kapetanios et.al (2006). The aforementioned tests are employed with the assistance of R software. The innovation of our survey stands on the fact that the particular method is used for first time in the case of agricultural products and especially in the case of dairy sector for countries of European Union given the implementation of CAP regime, amplifying the validity of PPP.

Keywords: Nonlinear Cointegration, Dairy sector, EU, PPP.

1 Introduction

PPP has been a surveyed extensively within the last few decades with the application of ADF and Johansen cointegration technique (Abuaf and Jorion, 1990; Balassa, 1964; Taylor and Taylor, 2004). Though, there has been no consensus on whether the real exchange rates are mean reverting or not while their results depend on a number of factors like the data span, the countries included in the sample, the methodology employed, and the exchange rates' regime under which the countries stand. In addition, the power of the particular stationarity test related to the widely used ADF test proved to be greater based on Monte Carlo simulation tests. This result is more evident in the region of the null where they are highly persistent (Kapetanios et al., 2003).

The present paper introduces the processes of nonlinear stationarity and cointegration tests in the field of agriculture. To be more specific, we employ the test of nonlinear unit root introduced by Kapetanios et al, (2003) in order to survey the

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validity of PPP in dairy products for different European countries. The aforementioned test is based on a STAR framework and the test involves detection of the presence of nonstationarity against nonlinear but globally stationary exponential smooth transition autoregressive processes (Kapetanios et al, 2003).

1.1 CAP and PPP in the sector of dairy products

The Common Agricultural Policy (CAP) until the year 2003 was implemented through a complex system including price support, production quotas, import restrictions, and export subsidies. Despite the production quotas, the EU produces more milk and milk products (such as butter and milk powder) than it needs to satisfy domestic consumption. This results in a structural surplus of dairy products, which is disposed of on internal and external markets using subsidies.

The CAP reform in the year 2003 initiated a great number of changes related either to the volume of production or even the pricing policy. In particular, the Single Farm Payment scheme has led to changes in resources' allocation given the decoupling of subsidies from production.

The reform and the farmers' adjustment to the new policy differ among different countries leading to modification in the adjusted pricing policy. As confirmed by a recent analysis conducted by Walford (2003), farmers are not taking decisions consistent with a less production-oriented environment and have distinctive patterns of adjustment to policy reform. Thus CAP will enable EU farmers to be more market oriented. This implies that they will produce having profit as criterion while the stability of their income is still guaranteed.

Evidently all these changes may well lead to a differentiation in the pricing policy and thus to a deviation from PPP given the uniform currency used within the EU.

1.2 CAP reform in dairy products

The regime of intervention prices was abolished for the dairy products as well as for rice and rye. However, intervention price support is still an important element of the EU sugar regime and to some extent cereals. For dairy products, the original proposal was always weak and the final agreement – to cut the butter intervention price by 25% by 2007/8 and skimmed milk powder (SMP) by 15% by 2006 – is extremely disappointing for the producers of dairy products. In fact, the changes to the milk powder regime do not differ from those agreed as part of Agenda 2000 in 1999. The final agreement will still leave the EU butter intervention price in 2007 at about 2,450 euro/tonne compared to the current world price of about 1,150 euro/tonne.3

The CAP reforms of 2003 were initiated with a view to making European agriculture more market orientated and less influenced by support mechanisms. The reforms were also aimed at the achievement of a WTO trade deal that would primarily assist developing and less developed countries. The main change for Europe's producers is a switch to decoupled farm payments (single farm payment), which issues payments based on historic production levels and enables producers to switch to the production of products demanded by the markets.

The single farm payment was strongly supported by farming lobbies. This was considered as a “freedom to farm”. In theory it enables producers to switch to more profitable or suitable agricultural enterprises without compromising the level of subsidy payments from Europe. However the contribution of this payment to farm income is not recognised when evaluating market returns for farm output and is leading to calls for stronger prices for farm output, irrespective of what the marketplace can deliver. The current strength of dairy markets has meant that this debate remains largely within the beef and lamb sectors to date. The annual reduction of this payment through may lead to a reduction of the value of this payment in time.

The EU offer to phase out export refunds by 2013 was a monumental step in a process towards freer international trade and a clear signal that the EU is prepared to do its part in supporting the developmental aspect of the current WTO trade negotiations. But irrespective of the WTO process, it has become increasingly difficult for Europe to justify continued subsidisation of exports as consumer food prices increased and reform of the refund system was always on the cards. However the EU’s WTO offer has not been matched by others and while a deal has not been achieved, Europe continues to work towards the complete abolition of export refunds by 2013. Future exports will therefore be possible only when the internal price is equal to the world price less tariffs (Mechemache et al., 2008) .

The intervention system has been a strong component of market management by Europe for the past number of years. This mechanism though is being removed as part of the CAP reforms and market forces will now be felt at producer level as little remains to cushion market fluctuation. The loss of intervention will introduce a seasonality cost to Irish production systems and lead to increased price volatility requiring a review of working capital required at farm level.

What is more significant concerning CAP for the dairy industry is the decision by the Commission to phase out milk quotas by the year 2015. The lifting of production restrictions has received a broad welcome as it will remove quota rental and purchasing costs and potentially enhances Europe’s relative global competitiveness. However increases in European production can lead to excess supply and consequently to lower commodity prices. This concern is based on the fact, that removing of market management measures can protect the market from depressions. This can lead to a cyclical problematic situation leading to a limited ability of the producers to finance their production. To be more specific, international dairy markets are characterized by times of weakened prices and without subsidies or market intervention, many producers will become unable to handle the management of their business. The management of quota abolition is therefore crucial for the evolution of Europe’s dairy farmers to an unmanaged marketplace. (Lelyon et al., 2008)

Direct payments are received by dairy farmers as compensation for reduction in the intervention prices. Thus, the prices might become even and doubled. Decoupled payments will not come into effect until the reforms are fully implemented unless member states decide to introduce it earlier. Furthermore, decoupled payments will still be partially linked to production, “What is valid is that the more quota the greater the premium.” The way the UK government tries to defend this position is by arguing that dairy farmers do not have to produce milk to get the payment but keep all land in ‘good agricultural condition’, so in effect it is decoupled (more information is awaited on this proposal and how it would be implemented) (Ramsden et al., 1999, Jongeneel et al., 2010).

All those changes take place within a broader environment regulated by WTO agreements. The last CAP reforms are in line with the basic lines of WTO. Though, the proposed tariff cuts may result in shocks for the world markets. In order stability to be sustained in the world markets a longer lead in time is necessary for the tariff reductions of this magnitude New regime of reduced tariffs and increased trade flows demands an extension of timelines for the internal reforms to take place, not only in EU but also in US.

The WTO process offers some mechanisms designed to assist product groups that could be severely undermined by an unbalanced trade deal. The sensitive products mechanism was designed to reduce the tariff reductions for such products at the cost of allowing a predetermined quantity of imports at a reduced tariff rate (Applying a tariff rate quota (TRQ)). However the TRQ methodology as currently proposed renders this tool redundant as the proposed TRQ for seeking sensitive product status is excessive. For potential sensitive dairy products such as butter and cheese, increased market access TRQ’s of 100% and 400% respectively are offered. This degree of market access will destabilise the internal market to such a degree that Europe cannot consider sensitive product status for dairy products (Viju, 2008).

The special safeguard mechanism can be used to protect exposed products for a limited period of time. This system must be implemented in a manner that ensures coverage for the duration of a market instability. This requires a balanced approach in nominating a product as “special” but even still it could be a contentious issue for many. This therefore may not be a sustainable position and product groups may lose in the long term.

Given that there are effectively no stabilising measures that can act to assist the market if required, the current tariff reductions are excessive and if left unchanged will act to destabilise global dairy markets. The WTO process must review its timelines to reflect the dynamics of the dairy sector.

Under these conditions we survey the validity of PPP with the assistance of non linear cointegration. Section 2 introduces the concept of non linear cointegration, section3 describes a few important studies on the issue, section 4 gives the econometric framework , section 5 presents the result and the final section conclude.

2. Definition of nonlinear cointegration

$y_t = (y_{1t},....,y_{nt})'$ is an n-dimensional random vector for each y_{it} is integrated of rank 1. This vector is said to be nonlinear cointegration if there is a vector as a function of time provided by $\alpha_t = (a_{1t},....,\alpha_{nt})'$ so that the product $\alpha_t' y_t$ is a I(0) time series.

The time-varying vector should have the following features:

1. The first term should be a nonzero-constant in order to can be normalized and to be derived the following term

$$\alpha_t = (1,....\alpha_{nt})' \quad (1)$$

2. each term of the aforementioned vector is a well defined function of a random variable S such that each term α_{it} to have a logistic smooth transition form provided by the following relationship;

$$a_{it} = a_i + G_{it} \quad (2)$$

Where;

$$G_{it} = \left(1 + \exp\{-\gamma_i (S_{it} - c_i)\}\right), \quad a_i, \gamma_i, c_i \textit{ parameters with } \gamma_i > 0 \quad (3)$$

The transition variables S_{it} are weakly stationary or deterministic variables. In this case α_t is the nonlinear cointegrating vector.

3. Literature Review

The existence of a unit root process in the real exchange rates functioned as an impediment to model the real exchange behavior with PPP. This has led to modifications of PPP theory. For instance Edison and Kloveland (1987), point out validity in the PPP theory only in the long run necessitates the use of long runs of data which in turn is accompanied by regime changes in tastes and technology and in a sequence permanent movements in the terms of trade or in the relative price of traded to nontraded goods. According to their findings, adjusting for "general equilibrium" shocks, enables them to reject the unit root in real exchange rates and provide support for the PPP hypothesis.

Altering the economic theory was not the correct way for scientists to confront investigators are looking to alternative frameworks within which to test for unit roots. The most widespread methodologies employed for the survey of PPP are related to the existence of nonlinearities as suggested by numerous studies (Pesaran and Potter, 1997; Balke and Fomby, 1997). To be more specific, Nonlinearities, Cointegration and nonstationarity has been extensively a subject of study by Enders and Granger (1998), Berben and van Dijk (1999), Caner and Hansen (2001), Lo and Zivot (2001) and Kapetanios and Shin (2001). STAR and ESTAR processes have been the nonlinear models validating PPP given that its ignorance leads to a bias against the long run PPP hypothesis.

4.Econometric Framework

4.1KSS test

The methodology applied in the present study for nonstationarity was initially introduced by Kapetanios et al., and is known as KSS. The model initially employed is the following;

$$y_t = \psi + \xi_t + x_t \qquad t = 1,2,....,T \tag{5}$$

$$\Delta \mathrm{x}_{\mathrm{t}} = \gamma x_{t-1}\left\{1-\exp(-\theta x_{t-1}^2)\right\} + \varepsilon_t \tag{6}$$

$$\Delta \mathrm{y}_{\mathrm{t}} = \xi + \gamma x_{t-1}\left\{1-\exp(-\theta x_{t-1}^2)\right\} + \varepsilon_t \tag{7}$$

where;

$$x_{t-1} = \left(y_{t-1} - \psi - \xi\right) \tag{8}$$

while the sum of squared residuals is given by the following equation;

$$SSE = \left(y_{t-1} - \psi - \xi\right)^2 + \sum_{t=2}^{T}\left[\Delta y_t - \xi - \gamma x_{t-1}\left\{1-\exp(-\theta x_{t-1}^2)\right\}\right]^2 \tag{10}$$

given that each square residual is normal and the concetrated log-likelyhood function is monotonic in the sum squred residuals.

For $\theta = 0$ it is valid that;

$$SSE = \left(y_{t-1} - \psi - \xi\right)^2 + \sum_{t=2}^{T}\left[\Delta y_t - \xi\right]^2 \tag{11}$$

Then the restricted maximum likelehood estimators are provided by the following relationships;

$$\tilde{\xi} = \frac{y_t - y_1}{T-1} \text{ and } \tilde{\psi} = y_t - \xi \tag{13}$$

The LM-type test is obtained by deriving the first derivative of SSE with respect to θ at θ=0, which is given by:

$$\sum_{t=1}^{T} (\Delta y_t - \xi) s_{t-1}^3 = \sum_{t=1}^{T} (\Delta y_t - \xi)(s_{t-1}^3 - s^{-3}) \tag{14}$$

where; $s_{t-1} = y_t - \tilde{\psi} - \tilde{\xi}(t-1)$ and s^{-3} is the mean of s_{t-1}^3.

The aforementioned equation is equivalent with the following auxiliary regression;

$$\Delta y_t = \xi + \delta s_{t-1}^3 + \varepsilon_t \tag{15}$$

$\mathrm{H}_0 : \delta = 0$

$\mathrm{H}_1 : \delta < 0$

The t – statistic employed for the aforementioned null hypotheses is provided by the following equation;

$$t_{NLSP} = \frac{\sum_{t=1}^{T} (s_{t-1}^3 - s^{-3})(\Delta y_t - \xi)}{\hat{\sigma}\left[\sum_{t=1}^{T} (s_{t-1}^3 - s^{-3})\right]^{1/2}} \tag{16}$$

$\hat{\sigma}$ denotes the standard error of the regression. In addition, given the validity of the functional central limit theorem and the continuous mapping theorem, under the null hypothesis the following relationships are derived;

$$\mathrm{T}^{-1/2} s_{[tr]} \Rightarrow \sigma V(r) \tag{17}$$

$$T^{-5/2}\sum_{t=1}^{T} s_{t-1}^{3} = \frac{1}{T}\sum_{t=1}^{T}\left(T^{-3/2} s_{t-1}^{3}\right) \Rightarrow \sigma^{3}\int_{0}^{1} V^{3}(r)dr \qquad (18)$$

$$\mathrm{T}^{-3/2}(s_{t-1}^{3} - s^{-3}) \Rightarrow \sigma^{3}\int_{0}^{1} V(r),$$
$$T^{-5/2}\sum_{t=1}^{T}\left(s_{t-1}^{3} - s^{-3}\right) \Rightarrow \sigma^{3}\int_{0}^{1} V(r) \qquad (19)$$

the[.] denoting the largest integer part stands for weak convergence,
$V(r) = W(r) - rW(1)$; standard Brownian bridge.
$V(r) = V^{3}(r) - \int_{0}^{1} V(r)$, standard Brownian motion.

In addition under the null, the validity of semi-martingale property and the standard results on weak convergence the following relationships can be proved;

$$\mathrm{T}^{-2}\sum_{t=1}^{T}\left(s_{t-1}^{3} - s^{-3}\right)\left(\Delta y_{t} - \xi\right) = T^{-2}\sum_{t=1}^{T}\left(s_{t-1}^{3} - s^{-3}\right)\varepsilon_{t} \Rightarrow \sigma^{4}\int V(r)dW(r) \qquad (20)$$

$$T^{-4}\sum_{t=1}^{T}\left(s_{t-1}^{3} - s^{-3}\right)^{2} \Rightarrow \sigma^{6}\int V^{2}(r)dW(r) \qquad (21)$$

Consistency of standard error and combination of the aforemnetioned results gives us the asymptotic null distributional result;

$$t_{NLSP} \Rightarrow \frac{\int_{0}^{1} V(r)dW(r)}{\left[\int_{0}^{1} V^{2}(r)dr\right]^{1/2}} \qquad (22)$$

Finally in order to eliminate potential dependence in errors we employ lagged values leading to the following equation;

$$\Delta y_t = \xi + \sum_{j=1}^{p} \phi_j \Delta y_{t-j} + \delta s_{t-1}^3 + e_t \quad e_t \text{ is the error.} \tag{23}$$

That is the modification of ADF in a nonlinear framework.

4.2 Nonlinear cointegration

The conditional exponential smooth transition regression error correction model (STR ECM) for Δy_t and the marginal vector autoregression (VAR) model for Δx_t is provided by the following equation;

$$\Delta y_t = \phi u_{t-1} + \gamma u_{t-1}(1 - e^{-\theta(u_{t-1}-c)^2}) + \omega' \Delta x_t + \sum_{i=1}^{p} \psi_i^{'} \Delta z_{t-1} + e_t \tag{24}$$

the test of the null of no cointegration against the alternative of globally stationary cointegration can be based on the single parameter θ.
We set the null hypothesis of no cointegration as;
$H_0 : \theta = 0$ (no cointegration)
$H_1 : \theta > 0$ (ESTR cointegration)
The null hypothesis implies in terms of the preceding model that;

$$\theta = \phi = 0 \tag{24.1}$$

The *FNEC* (*tNEC)* test refers to the *F*-type (*t*-type) statistic obtained directly from the nonlinear ESTR error correction regression, whereas the *tNEG* test is the nonlinear analogue to the Engle and Granger (EG) statistic for linear cointegration.

$$\hat{u}_t = y_t - \hat{\beta}_x^{'} x_t \tag{24.2}$$

The auxiliary regression under which $\phi \neq 0$ takes the following form;

$$\Delta y_t = \delta_1 \hat{u}_{t-1} + \delta_2 \hat{u}^2{}_{t-1} + \delta_3 \hat{u}_{t-1}^3 + \omega' \Delta x_t + \sum_{i=1}^{p} \psi_i^{'} \Delta z_{t-1} + e_t \tag{25}$$

That is the cubic polynomial nonlinear error correction (NEC) model.

For this model, we consider an F-type test for $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ that is given by the following relation;

$$F_{NEC} = \frac{\left(SSR_0 - SSR_1\right)/3}{SSR_o/(T-4-p)} \tag{26}$$

Under the assumption that $\phi = 0$ the NEC model takes the following form;

$$\Delta y_t = \delta\, \hat{u}_{t-1}^3 + \omega' \Delta x_t + \sum_{i=1}^{p} \psi_i^{'} \Delta z_{t-1} + e_t \tag{27}$$

In this case we employ an t-type test for δ=0 (no cointegration! against d < 0 (ESTR cointegration) and is provided by the following statistic;

$$t_{NEC} = \frac{\hat{u}_{-1}^{3'} Q_1 \Delta y}{\sqrt{\hat{\sigma}^2 \hat{u}_{-1}^{3;} Q_1 \hat{u}_{-1}^3}} \tag{28}$$

where;

$$\hat{\sigma}_{NEC}^2 = T^1 \sum_{t=1}^{T} (\Delta y_t - \hat{\delta}\, \hat{u}_{t-1}^3 - \hat{\omega}' \Delta x_t - \sum_{i=1}^{p} \psi_i^{'} \Delta z_{t-1} + e_t)^2$$

$$\Delta Y = \left(\Delta y_i, \ldots\ldots, \Delta y_T\right)' \quad Q_1 = I_T - S(S'S)^{-1} S'$$

$$S = (\Delta X, \Delta Z_{-1}, \ldots\ldots., \Delta Z_{-p}),\ \text{Tx(k+p(k+1)) data matrix} \tag{29}$$

$$\Delta X = \left(\Delta x_i, \ldots\ldots, \Delta x_T\right)' \quad \Delta Z_{-i} = \left(\Delta z_{1-i}, \ldots\ldots, \Delta z_{T-i}\right)'$$

$\hat{\delta}, \hat{\omega}, \hat{\psi}_i$ are the OLS estimates of $\delta, \omega, \psi_i /$

5.Data

In the present study real exchange rates based on dairy products for fifteen European countries of different economic status philosophy and productivity ability in dairy products are employed for the nonlinear stationarity test indroduced by Kapetanios et al (2003). The time series are consisted of monthly observations extend from 1.1995-12.2007. The results obtained are derived with the application of R software. In addition the nonlinear cointegration based on EG initial model involved the differences of the dairy prices between the European country and USA in logarithmic form and the nominal exchange rate of Euros/dollar also in logarithmic form for the same time period.

6. Results

The results of the nonlinear unit root process are presented on table 1. The results are based on the estimation of the model provided by equation7. the number of augmentations must be selected prior to the test to accommodate possible serially correlated errors. For comparison purposes we provide the results derived by Zafeiriou (2009), for the same data and the same time period.

Table 1. Unit Roots tests against nonlinear STAR process

Country	ADF	t_{NLS}
qbeld	-2.723 (2)	-3.58 *
qbuld	-2.725(0)	-2.652
qcypd	-2.008(2)	-2.314(2)
qdand	-1.93(0)	-1.874(0)
qestd	-1.817(2)	-1.4235(2)
qfind	-2.019(0)	-3.042(0)*
qfrand	-2.2436(1)	-2.2542(1)
qgerd	-1.7829(2)	-1.9225(2)
qgrbrd	-1.545(1)	-1.545(1)
qgreed	-1.792(0)	-1.792(0)
qird	-1.096(0)	-1.122(0)
qitad	-2.2132(2)	-3.842(2)*

a Indicates rejection of the null of a unit root at the 5% significance level.

Evidently, the non linear stationarity test is able to reject a unit root in many cases, whereas the linear DF tests fail, providing some evidence of nonlinear mean-reversion in both real exchange rates in the case of dairy products.

The next step in our study involves the application of non linear cointegration.

In the next step employing the appropriate augmentation model we surveyed the validity of PPP through cointegration of the dairy products' prices differences and its respective exchange rates. The results of this process are provided in the next table 12.

Table 12. Cointegration tests and estimates of the ESTAR parameter for differences in dairy prices between the European countries and exchange rates

Country	t_{NEC}	$\hat{\theta}$	t_{θ}
qbeld	-3,42**	0.0007	2.8
qbuld	-3.75**	0.0011	2.65
qcypd	-4.2*	0.0009	3.4
qdand	-2.68	0.0004	2.2
qestd	-4.88*	0.0011	3.9
qfind	-7.32*	0.00112	5.4
qfrand	-4.72*	0.0014	2.1
qgerd	-5.21*	0.0013	3.09
qgrbrd	-3.82**	0.0018	3.6
qgreed	-4.77*	0.0011	4.01
qird	-4.65*	0.0012	2.01
qitad	-4.76*	0.0018	3.07
qlatd	-4.55*	0.0043	4.1

The success in rejecting the null of no cointegration is less marked for *tNEC*, with only five rejections at standard significance levels, although three of these reject also at the 1% A further two *tNEC* statistics are quite close to the 10% critical value.

7. Conclusions

Empirical univariate analysis of nonstationarity against stationarity has been an integral part of time series econometrics. However, the emphasis of the earlier literature was on the examination of the linear model, implicitly disregarding any possible nonlinearities in the series under consideration. This paper complements other recent studies in trying to survey this scientific field.

According to the results of the nonstationarity test introduced by Kapetanios et al, indicate that this test is a useful tool for time series known to be stationary but also persistent like that of the real exchange rates. In addition the ESTR model is evidently a better alternative compares to those of AR models in such cases (Kapetanios et al., 2003).

Finally regarding the nonlinear cointegration we confirmed that a simple direct cointegration test procedure that it has better power than the linear cointegration tests that ignore the nonlinearities. Unlike linear cointegration tests, the nonlinear tests find substantial evidence of cointegration in diary prices differences and exchange rates for the European countries employed.

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Appendix – The R code

```
sim=function(t=25,a=1,b=1,d=0){
# data generation under H0
t=t+5 # check the delay parameter d, and the first five value is ...
y2=rep(0,t)
y2[1]=rnorm(1)
for(i in 2:t){
ee=rnorm(1)
y2[i]=y2[i-1]+ee
}
y3=rep(0,t)
y3[1]=rnorm(1)
for(i in 2:t){
ee=rnorm(1)
y3[i]=y3[i-1]+ee
}
y1=rep(0,t)
for(i in 1:t){
ee=rnorm(1)
y1[i]=a*y2[i]+b*y3[i]+ee
}
# Compute the F Value
diff_y20=diff(y2)
d1=5-d
d2=t-1-d
diff_y2=c(diff_y20[d1:d2])
yy2=diff_y2*y2[6:t]
yy21=diff_y2^2*y2[6:t]
yy22=diff_y2^3*y2[6:t]
diff_y30=diff(y3)
d1=5-d
d2=t-1-d
diff_y3=c(diff_y30[d1:d2])
yy3=diff_y3*y3[6:t]
yy31=diff_y3^2*y3[6:t]
yy32=diff_y3^3*y3[6:t]
y11=matrix(y1[6:t],t-5,1)
y22=y2[6:t]
y33=y3[6:t]
x=cbind(y22,yy2,yy21,yy22,y33,yy3,yy31,yy32)
bt=solve(t(x)%*%x)%*%t(x)%*%y11
rr=matrix(c(a,0,0,0,b,0,0,0),8,1)
```

```
st=(t(y11-x%*%bt)%*%(y11-x%*%bt))/(t-8)
F_v=t(bt-rr)%*%solve(st[1]*solve(t(x)%*%x))%*%(bt-rr)/6
return(F_v)
}
# simulation:
F_v=rep(0,10000)
for(i in 1:10000){
F_v[i]=sim(25,1,1,0)
}
hist(F_v,breaks=40)
q_val=quantile(F_v,probs=c(99,97.5,95,90,10,5,2.5,1)/100)
q_val
```

(2) Testing for nonlinear cointegration for PPP data set

```
p1=100*(log(PZUNEW)-log(PZUNEW[1]))
p2=100*(log(PC6IT)-log(PC6IT[1]))
s=100*(log(1/EXRITL)-log(1/EXRITL[1]))
PPP.data=ts(cbind(p1,p2,s))
plot(PPP.data,plot.type="single",col=2:4)
abline(h=0, col = "gray60")
dd=1
diff_p2=diff(p2)
c=length(diff_p2)-dd
diff_p2=diff_p2[1:c]
g=dd+2
   pp2=p2[g:length(p2)]

p22=diff_p2*pp2
p23=diff_p2^2*pp2
p24=diff_p2^3*pp2
diff_s=diff(s)
diff_s=diff_s[1:c]
ss=s[g:length(s)]
s2=diff_s*ss
s3=diff_s^2*ss
s4=diff_s^3*ss
pp1=p1[g:length(p1)]
lm0=lm(pp1~pp2+ss-1)
lm1=lm(pp1~pp2+p22+p23+p24+ss+s2+s3+s4-1)
rss0=sum(residuals(lm0)^2)
rss1=sum(residuals(lm1)^2)
F_val=((rss0-rss1)/6)/(rss1/(length(pp1)-8))
F_val
```