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A Panel Cointegration Analysis of the Euro area money demand.

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Abstract

Using panel cointegration structure for eleven European monetary union (EMU) countries we check Driscoll money demand model (where three different types of variables are used) that the variables of this model has a long run relationship or not. These variables are Real M3, Real GDP and opportunity cost. As opportunity cost we use long term interest rate, deposit interest rate and spread between long term and short term interest rate. Eleven countries (which are the founding members of EMU) quarterly data are taken from Eurostat and OECD website begin from 1999-Q1 to 2009-Q3. With the help of Eviews 7 software two types of panel unit root tests (common unit root processes and individual unit root processes) and three types of panel cointegration tests are used to analyze quarterly observations. In both types of panel unit root tests, results suggest that the first difference of all the series is stationary. For the panel cointegration tests, results support the stability of long run money demand in the Euro area.

Key Words: Panel cointegration, Unit roots, Money demand, Euro area, M3.

1 Introduction

Effective and stable money demand estimations are the precondition for the monetary authorities to design an effective monetary policy. For that reason to find the determinants of the demand for money a lot of empirical studies are devoted to investigate what are the main determinants of the money demand function. John Maynard Keynes in his famous 1936 book “The general Theory of Employment, Interest and Money” developed a theory of money demand which he called liquidity preference theory. There he emphasized the importance of interest rates. And he postulated three motives behind the demand for money the transaction motive, the precautionary motive and speculative motive. After Keynes (1936) a lot of literatures try to explore this issue on both theoretical and empirical level. Some research efforts are often giving conflicting assumptions. The most frequently explanatory variables in money demand function are the economic activity variables, opportunity cost and various other variables.

In this paper the hypothesis of money demand function is tested using panel cointegration method. The cross sectional approach was first introduced Mulligan and Sala-i-Martin (1992) who estimated U.S money demand using data from the federal state. Further advancing Driscoll (2004) analyze regional U.S. money demand by exploiting the panel structure of the data. Here, following Driscoll (2004) empirical approach, the aim of this paper is to check the stable long run money demand relationship to the founding member of European Monetary Union (EMU) countries in the Euro area.

The paper organized as follows: In the next section we briefly describe the econometric model of the money demand. In section 3 we discuss data and its limitation. Section 4 and 5 discusses the theory of panel unit root tests and panel cointegration tests. Section 6 gives the results and discussion and the last section is conclusion.

2 An Econometric model of the money demand

A consumer wants to maximize her life time utility. She can derive utility from two sources

- Consumption, denoted C_t
- Holdings real balance denoted $\frac{M_t}{P_t}$

where M_t=Nominal balance and P_t=price level

So her standard maximization utility function can be derived as follows

$$max_{(C_t),(M_t)} \left[\sum_{t=o}^{\infty} \beta^t U \left(C_t, \frac{M_t}{P_t} \right) \right] \tag{2.1}$$

where $\beta = \frac{1}{1+\theta}$, and θ is a discount factor.

Each period the consumer receives an income Y_t . She also has money left over from last period M_{t-1} whose current real value is $\frac{M_{t-1}}{P_t}$. She must choose to allocate these resources as

- As consumption C_t
- As new money holdings, with real value $\frac{M_{t-1}}{P_t}$

So the corresponding budgets constraints is

$$C_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} = Y_t + (1 + i_{t-1}) \frac{B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} \tag{2.2}$$

where B_t= nominal (Government) bond holdings.

In words the consumer chooses a sequence of consumption C_t, nominal balance M_t and nominal (Government) bond holdings B_t. i_{t-1} is the nominal interest rate on nominal bond holdings at time $t-1$.
The Fisher type equation is an equation that defines the real interest rate (r_t), by taking into account the actual price level:

$$\frac{(1+i_t)P_t}{P_{t+1}} = (1+r_t) \tag{2.3}$$

stating that if we have an nominal interest rate i_t at time t but in fact the price levels increasing from t to $t+1$ (from P_t to P_{t+1}) then the real interest would be felt smaller.

Let λ_t denote the sequence of Lagrange multiplier, from the method of Lagrange multiplier, from equation (2.1) and (2.2) we get the Lagrange function

$$G = \sum_{t=0}^{\infty}\left\{\beta^t U\left(C_t, \frac{M_t}{P_t}\right) - \lambda_t\left(C_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} - Y_t - (1+i_{t-1})\frac{B_{t-1}}{P_t} - \frac{M_{t-1}}{P_t}\right)\right\} \tag{2.4}$$

Now differentiate equation (2.4) with respect to three choice variables ($C_t, \frac{M_t}{P_t}, \frac{B_t}{P_t}$) for $t = 1,2,\ldots$ to obtain the following three sets of first order condition.
Differentiate equation (2.4) with respect to C_t and equating to zero we get

$$\frac{d}{dC_t}\left\{\sum_{t=0}^{\infty}\left\{\beta^t U\left(C_t, \frac{M_t}{P_t}\right) - \lambda_t\left(C_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} - Y_t - (1+i_{t-1})\frac{B_{t-1}}{P_t} - \frac{M_{t-1}}{P_t}\right)\right\}\right\} = 0$$

or

$$\beta^t \frac{dU\left(C_t, \frac{M_t}{P_t}\right)}{dC_t} - \lambda_t = 0.$$

With $U_{C_t} = \frac{dU\left(C_t, \frac{M_t}{P_t}\right)}{dC_t}$ we thus have

$$\beta^t U_{C_t} = \lambda_t \tag{2.5}$$

Let $m_t = \frac{M_t}{P_t}$. Differentiating equation (2.4) with respect to $\frac{M_t}{P_t}$ and equating to zero we get

$$\frac{d}{dm_t}\left\{\sum_{t=0}^{\infty}\left\{\beta^t U\left(C_t, \frac{M_t}{P_t}\right) - \lambda_t\left(C_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} - Y_t - (1+i_{t-1})\frac{B_{t-1}}{P_t} - \frac{M_{t-1}}{P_t}\right)\right\}\right\} = 0$$

or

$$\beta^t \frac{dU\left(C_t, \frac{M_t}{P_t}\right)}{dm_t} - \lambda_t + \frac{d}{dm_t}\left\{\sum_{t=0}^{\infty}\left(\lambda_t \frac{M_{t-1}}{P_t}\right)\right\} = 0.$$

With $U_{m_t} = \frac{dU\left(C_t, \frac{M_t}{P_t}\right)}{dm_t}$ we thus have

$$\beta^t U_{m_t} - \lambda_t + \frac{d}{dm_t}\left(\lambda_t \frac{M_{t-1}}{P_t} + \lambda_{t+1}\frac{M_t}{P_t} * \frac{P_t}{P_{t+1}}\right) = 0$$

or

$$\beta^t U_{m_t} = \lambda_t - \lambda_{t+1}\frac{P_t}{P_{t+1}} \tag{2.6}$$

Finally, by differentiating equation (2.4) with respect to $\frac{B_t}{P_t}$ and equating to zero we get

$$\frac{d}{d\frac{B_t}{P_t}}\left\{\sum_{t=0}^{\infty}\left\{\beta^t U\left(C_t, \frac{M_t}{P_t}\right) - \lambda_t\left(C_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} - Y_t - (1+i_{t-1})\frac{B_{t-1}}{P_t} - \frac{M_{t-1}}{P_t}\right)\right\}\right\} = 0$$

$$-\lambda_t - \frac{d}{d\frac{B_t}{P_t}}\left\{\sum_{t=0}^{\infty}(1+i_{t-1})\left(\lambda_t\frac{B_{t-1}}{P_t}\right)\right\} = 0$$

$$-\lambda_t - \frac{d}{d\frac{B_t}{P_t}}\left((1+i_{t-1})\,\lambda_t\frac{B_{t-1}}{P_t} + (1+i_t)\lambda_{t+1}\frac{B_t}{P_t} * \frac{P_t}{P_{t+1}}\right) = 0$$

or

$$\lambda_t = \lambda_{t+1}\frac{(1+i_t)P_t}{P_{t+1}} = \lambda_{t+1}(1+r_t) \tag{2.7}$$

Now we have all ingredients to solve the model. Putting (2.7) into (2.6) we obtain,

$$\beta^t U_{m_t} = \lambda_t\left(1 - \frac{\frac{P_t}{P_{t+1}}}{1+r_t}\right)$$

and using (2.5) we obtain, after reduction,

$$U_{m_t} = U_{C_t}\left(1 - \frac{\frac{P_t}{P_{t+1}}}{1+r_t}\right)$$

Now using (2.3) we get

$$U_{m_t} = \left(1 - \frac{1}{1+i_t}\right)U_{C_t} = \frac{i_t}{(1+i_t)}U_{C_t}$$

or

$$\frac{U_{m_t}}{U_{C_t}} = \frac{i_t}{1+i_t} \tag{2.8}$$

The actual utility function sometimes called is specified as follows

$$U\left(C_t, \frac{M_t}{P_t}\right) = \frac{C_t^{1-\sigma}-1}{1-\sigma} + b_t^{\delta}\frac{\left(\frac{M_t}{P_t}\right)^{1-\gamma}-1}{1-\gamma}$$

or

$$U\left(C_t, \frac{M_t}{P_t}\right) = \frac{C_t^{1-\sigma}-1}{1-\sigma} + b_t^{\delta}\frac{(m_t)^{1-\gamma}-1}{1-\gamma} \tag{2.9}$$

where b_t stand for shift on the preference for money holding, using the cash–in-advance and resource constraints equation (2.8) and equation (2.9) leads to money demand equation

with this utility function,

$$U_{m_t} = \frac{d}{d_{m_t}}\left(\frac{C_t^{1-\sigma}-1}{1-\sigma}\right) + \frac{d}{d_{m_t}}\left(b_t^{\delta}\frac{(m_t)^{1-\gamma}-1}{1-\gamma}\right) = b_t^{\delta}(m_t)^{-\gamma} \tag{2.10}$$

and

$$U_{C_t} = \frac{d}{dc_t}\left(\frac{C_t^{1-\sigma}-1}{1-\sigma}\right) + \frac{d}{dc_t}\left(b_t^{\delta}\frac{(m_t)^{1-\gamma}-1}{1-\gamma}\right) = C_t^{-\sigma} \tag{2.11}$$

Now putting the expressions for U_{m_t} and U_{C_t} in equation (2.8) we get

$$\frac{b_t^{\delta}(m_t)^{-\gamma}}{C_t^{-\sigma}} = \frac{i_t}{1+i_t}$$

or

$$b_t^{\delta}(m_t)^{-\gamma} = C_t^{-\sigma}\left(\frac{i_t}{1+i_t}\right)$$

Taking logs on both sides we get

$$lnb_t^{\delta} + ln(m_t)^{-\gamma} = lnC_t^{-\sigma} + ln\left(\frac{i_t}{1+i_t}\right)$$

or

$$\gamma lnm_t = \sigma lnC_t - ln\left(\frac{i_t}{1+i_t}\right) + \delta lnb_t$$

Rewriting this, we thus have

$$ln\left(\frac{M_t}{P_t}\right) = \frac{\sigma}{\gamma}\ln(C_t) - \frac{1}{\gamma}ln\left(\frac{i_t}{1+i_t}\right) + \frac{\delta}{\gamma}\ln(b_t) \quad (2.12)$$

Money demand then depends on real income, the opportunity cost of holding money i_t and exogenous preference shift.

Now suppose there are N countries indexed by $j \,\epsilon (1,2,..N)$. These countries share a common monetary authority, individual and bank can hold bank deposits or bonds, bonds bear interest rate, countries deposits rate also have an interest rate, b_t assumed to be the same in all countries so equation (2.12) can be written in the following format

$$ln\left(\frac{M_{jt}}{P_{jt}}\right) = \frac{\sigma}{\gamma}\ln(C_{jt}) - \frac{1}{\gamma}ln\left(\frac{i_{jt}}{1+i_{jt}}\right) + \frac{\delta}{\gamma}\ln(b_t) \quad (2.13)$$

Let

$$\tilde{m}_{jt} = \ln(M_{jt}),\, \tilde{p}_{jt} = \ln(P_{jt}),\, \tilde{y}_{jt} = \ln(C_{jt}),\, \tilde{\imath}_{jt} = ln\left(\frac{i_{jt}}{1+i_{jt}}\right), \alpha_t = \frac{\delta}{\gamma}\ln(b_t),\, \beta_1 = \frac{\sigma}{\gamma}, \beta_2 = -\frac{1}{\gamma}$$

Then equation (2.13) can be rewritten as

$$\tilde{m}_{jt} - \tilde{p}_{jt} = \alpha_t + \beta_1\tilde{y}_{jt} + \beta_2\tilde{\imath}_{jt} + \varepsilon_{jt} \quad (2.14)$$

Here ε_{jt} represent country specific shocks to money demands .The preference parameters σ ,γ, b_t are identical across countries.

For panel cointegration analysis equation (2.14) is our empirical money demand model

where
$\tilde{m}_{jt}$=Broad money (M3)
$\tilde{p}_{jt}$=GDP deflator
$\tilde{y}_{jt}$=Real GDP
$\tilde{\imath}_{jt}$=Opportunity cost
According to ECB's (European Central Bank) definition of euro area monetary aggregates, Broad money (M3) includes

Currency in circulation
+
Overnight deposits
+
Deposits with an agreed maturity up to 2 years
+
Deposits redeemable at a period of notice up to 3 months
+
Repurchase agreement
+
Money market fund (MMF) shares/units
+
Debt securities up to 2 years

3 Data

The eurozone, officially the euro area, is an economic and monetary union (EMU) of 16 European Union (EU) member states which have adopted the euro currency as their sole legal tender. It currently consists of Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia and Spain. Table 1 shows the country and adopted year of the euro area.

Table 1: Country and adopted year of the euro area.

Country	Adopted year
Austria	1 January 1999
Belgium	1 January 1999
Cyprus	1 January 2008
Finland	1 January 1999
France	1 January 1999
Germany	1 January 1999
Greece	1 January 2001
Ireland	1 January 1999
Italy	1 January 1999
Luxembourg	1 January 1999
Malta	1 January 2008
Netherlands	1 January 1999
Portugal	1 January 1999
Slovakia	1 January 2009
Slovenia	1 January 2007
Spain	1 January 1999

For panel analysis of euro area money demand, data are taken from all eleven founding members of European monetary Union (EMU) Includes **Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherland, Portugal, Spain**. Quarterly data are taken from the start of EMU on 1999 until the third quarter of 2009. This gives 11x43=473 observations. All the monetary aggregate data are taken from Eurostat website (Banks' balance sheet assets and liabilities-Quarterly data). Except currency in circulation due to unavailability of the data.

Figure 1: Comparisons between EMU 16 countries M3 and 11 countries M3

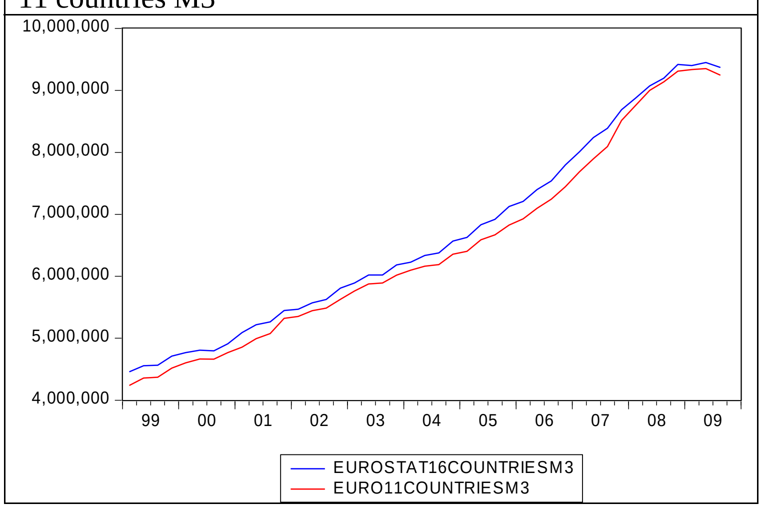
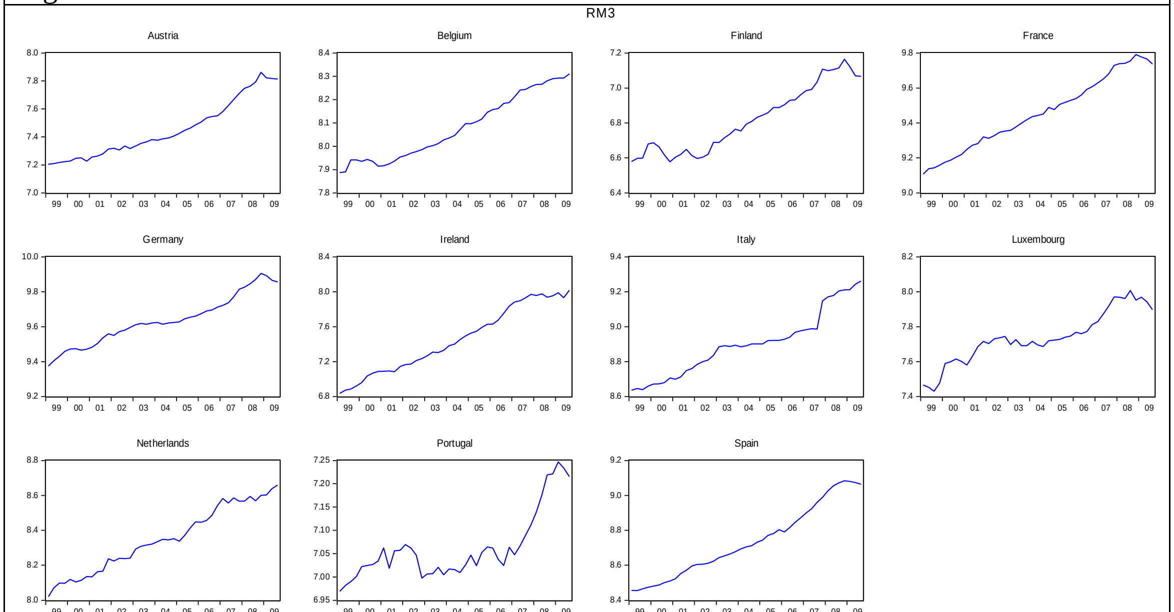


Figure 2: Real M3 of individual cross section



GDP, GDP deflator, Long-term interest rate on government bonds and short term interest rate are taken from Organisation for Economic Co-operation and developments (OECD) Economic outlook No 86: Annual and Quarterly data vol 2009 release 03. GDP and GDP deflator are in volume and from its market price. By using GDP and GDP deflators we can easily calculated Real GDP. Dividing the GDP by the GDP deflator and multiplying it by 100 would give the figure of real GDP. Real GDP and M3 data are seasonally adjusted with census x12 methodology. All variables are demeaned from their cross-sectional average and are given in logs.

Figure 3: Real GDP (individual cross section)

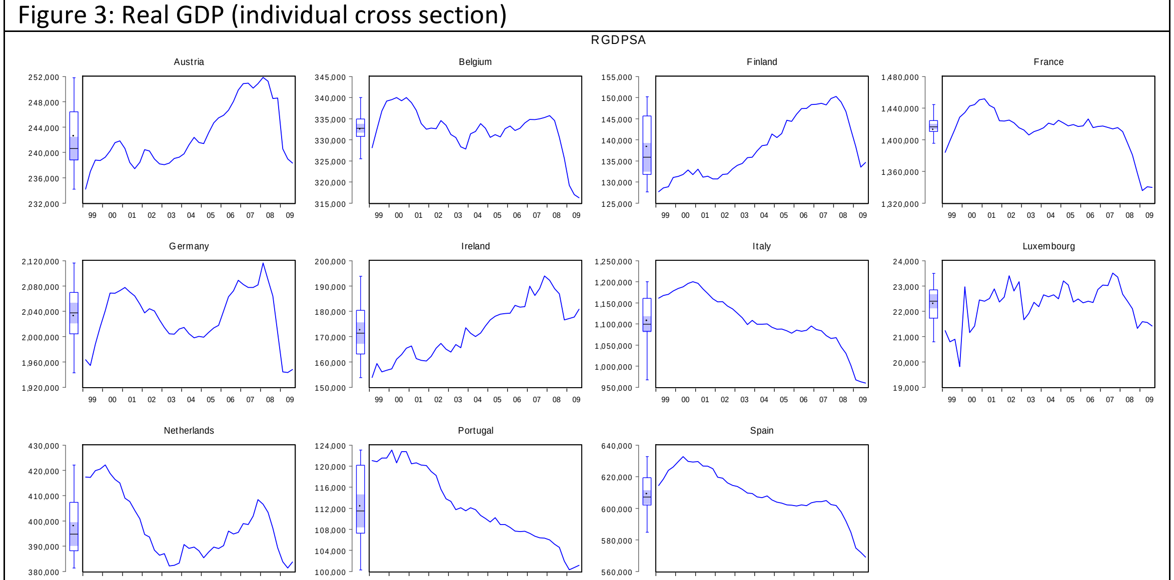
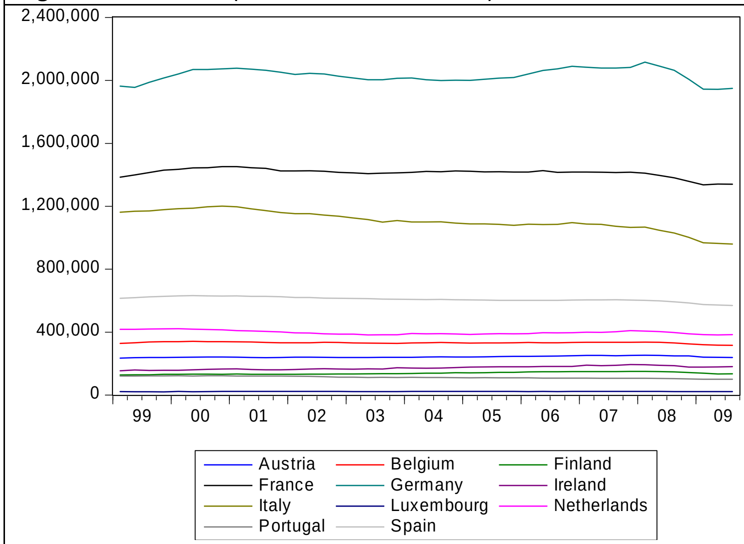


Figure 4: Real GDP (combine cross section)



Interest rate:

Three different types of opportunity cost are use as a interest rate they are

(1) Deposit interest rate.
(2) Long term interest rate.
(3) Spread between long term and short term interest rate.

For deposit interest rate, MFI interest rate statistics of the ECB refers to the deposit with agreed maturity up to two years. Long term interest rates are country specific 10 years government bond yields.

All data here are quarterly and begins from 1999-Q1 to 2009-Q3.

Figure 5, 6 and 7 display three different types of opportunity costs

Figure 5: Long term interest rate (combine cross section)

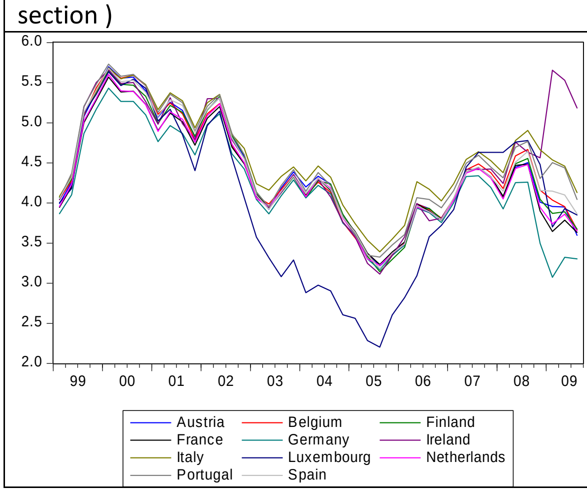


Figure 6: Deposit interest rate (combine cross section)

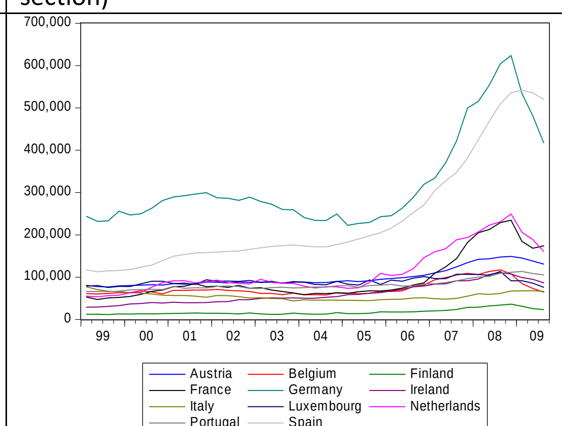
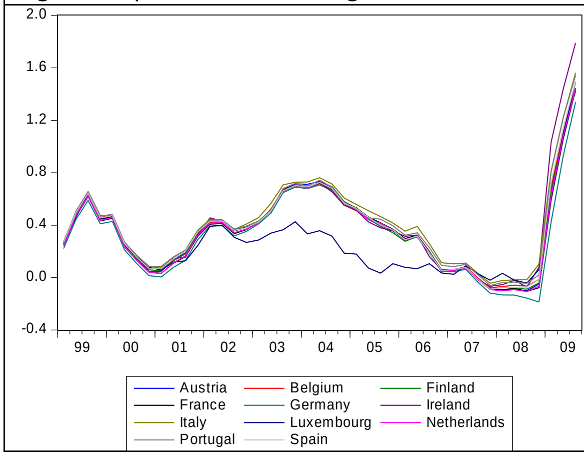


Figure 7: Spread between long term and short term interest rate (combine cross section)



4 Panel unit root test

We check stationarity of data through panel unit root test. Panel unit root test are not similar to unit root test. There are two types of panel unit root processes.

When the persistence parameters are common across cross-section then this type of processes is called a common unit root process. Levin, Lin and Chu (LLC) employ this assumption.

When the persistent parameters freely move across cross section then this type of unit root process is called an individual unit root process. The Im, Pesaran and Shin (IPS), Fisher-ADF and Fisher-PP test are based on this form.

4.1 Tests within Common Unit root processes

Levin, Lin and Chu (LLC)

Let $\{y_{it}\}$ be a stochastic process for a panel individual $i = 1,2, \ldots.., N$ and each individual (country) contain $t = 1,2, \ldots, T$ time series observation. Here we determine whether $\{y_{it}\}$ is integrated for each individual of the panel.

Assume that $\{y_{it}\}$ is generated by one of the following three models

Model 1: $\Delta y_{it} = \delta y_{it-1} + \zeta_{it}$.

Model 2: $\Delta y_{it} = \alpha_{0i} + \delta y_{it-1} + \zeta_{it}$

Model 3: $\Delta y_{it} = \alpha_{0i} + \alpha_{0i} t + \delta y_{it-1} + \zeta_{it}$, where $-2 < \delta \leq 0$ for $i = 1,2, \ldots, N$.

where $\Delta y_{it} = y_{it} - y_{it-1}$

The null and alternative hypothesis for model 1 may be written as

$$H_0: \delta = 0$$
$$H_1: \delta < 0$$

The null and alternative hypothesis for model 2 may be written

$$H_0: \delta = 0 \text{ where } \alpha_{0i} = 0 \text{ for all } i$$
$$H_1: \delta < 0 \; for \; \alpha_{0i} \in R$$

The null hypothesis and alternative hypothesis of model 3 is

$$H_0: \delta = 0 \text{ where } \alpha_{1i} = 0 \text{ for all } i$$
$$H_1: \delta < 0 \; for \; \alpha_{1i} \in R$$

The error process ζ_{it} is distributed independently across individuals and follows a stationary invertible ARMA process for each individual.

$$\zeta_{it} = \sum_{j=1}^{\infty} \theta_{ij}\zeta_{it-j} + \varepsilon_{it}.$$

Test procedure:

According to Levin, Lin and Chu (2002) the maintain hypothesis is

$$\Delta y_{it} = \delta y_{it-1} + \sum_{L=1}^{P_i} \theta_{iL}\Delta y_{it-L} + \alpha_{mi}d_{mt} + \varepsilon_{it}, \qquad m = 1,2,3$$

From the original paper (Levin et al (2002)) follow a three step procedure. In step 1 they carry out separate ADF regressions for each individual in the panel, and generate two orthogonalized residuals. Step 2 requires estimating the ratio of long run to short run innovation standard deviation for each individual. In the final step they compute the pooled t-statistics.

Step 1

For each individual i , first need to implement the ADF regression

$$\Delta y_{it} = \delta_i y_{it-1} + \sum_{L=1}^{P_i} \theta_{iL}\Delta y_{it-L} + \alpha_{mi}d_{mt} + \varepsilon_{it}, \qquad m = 1,2,3 \qquad (4.1)$$

The lag order P_i is permitted to vary across individuals.

Now for determined auto regression order P_i in equation (4.1) first run two auxiliary regressions to generate orthogonalized residuals. Regress Δy_{it} and y_{it-1} against $\Delta y_{it-L}(L = 1, .. P_i)$ and the appropriate deterministic variables, d_{mt}, then save the residuals $\hat{e}_{it}$ and $\hat{v}_{it-1}$ from these regressions.

$$\hat{e}_{it} = \Delta y_{it} - \sum_{L=1}^{P_i} \hat{\pi}_{iL}\Delta y_{it-L} - \hat{\alpha}_{mi}d_{mt}$$

And

$$\hat{v}_{it-1} = y_{it-1} - \sum_{L=1}^{P_i} \tilde{\pi}_{iL}\Delta y_{it-L} - \tilde{\alpha}_{mi}d_{mt}$$

To control for heterogeneity across individuals, further normalize $\hat{e}_{it}$ and $\hat{v}_{it-1}$ by the regression standard error from equation (4.1)

$\tilde{e}_{it} = \frac{\hat{e}_{it}}{\hat{\sigma}_{\varepsilon i}}$, $\tilde{v}_{it-1} = \frac{\hat{v}_{it-1}}{\hat{\sigma}_{\varepsilon i}}$, where $\hat{\sigma}_{\varepsilon i}$ is the regression standard error in (4.1)

Step 2

Under the null hypothesis of a unit root, the long-run variance for model 1 can be estimated as follows:

$$\hat{\sigma}_{yi}^2 = \frac{1}{T-1}\sum_{t=2}^{T} \Delta\, y_{it}^2 + 2\sum_{L=1}^{\bar{K}} w_{\bar{K}l}\left[\frac{1}{T-1}\sum_{t=2+L}^{T} \Delta y_{it}\Delta y_{it-L}\right] \qquad (4.2)$$

For model 2, replacing Δy_{it} in equation (4.2) with $\Delta y_{it} - \overline{\Delta y_{it}}$, where $\overline{\Delta y_{it}}$ is the average value of Δy_{it} for individual i. For model 3 time trend should be remove before estimating long-run variance. The truncation lag parameter $\bar{K}$ can be data dependent. The sample covariance weights $w_{\bar{K}l}$depend on the choice of Kernel.

For each individual, define the ratio of the long-run standard deviation to the innovation standard deviation,

$$s_i = \frac{\sigma_{yi}}{\sigma_{\varepsilon i}}$$

Denote its estimate by

$$\hat{s}_i = \frac{\hat{\sigma}_{yi}}{\hat{\sigma}_{\varepsilon i}}$$

Let the average standard ratio be $S_N = \frac{1}{N}\sum_{i=1}^{N} s_i$ and its estimator $\hat{S}_N = \frac{1}{N}\sum_{i=1}^{N} \hat{s}_i$.

Step 3

Lastly pool all cross sectional and time series observation to estimate

$$\tilde{e}_{it} = \delta \tilde{v}_{it-1} + \tilde{\varepsilon}_{it}$$

Based on a total of $N\tilde{T}$observations, where $\tilde{T} = T - \bar{P} - 1$ is the average number of observations per individual in the panel, and $\bar{P} = \frac{1}{N}\sum_{i=1}^{N} P_i$.

The conventional regression t-statistics for testing $\delta = 0$ is given by

$$t_\delta = \frac{\hat{\delta}}{STD(\hat{\delta})}$$

where

$$\hat{\delta} = \frac{\sum_{i=1}^{N}\sum_{t=2+P_i}^{T} \tilde{v}_{it-1}\tilde{e}_{it}}{\sum_{i=1}^{N}\sum_{t=2+P_i}^{T} \tilde{v}_{it-1}^2}$$

and

$$STD(\hat{\delta}) = \hat{\sigma}_{\tilde{\varepsilon}} \left[\sum_{i=1}^{N}\sum_{t=2+P_i}^{T} \tilde{v}_{it-1}^2\right]^{-1/2}$$

$$\hat{\sigma}_{\tilde{\varepsilon}}^2 = \left[\frac{1}{N\tilde{T}}\sum_{i=1}^{N}\sum_{t=2+P_i}^{T} \left(\tilde{e}_{it} - \hat{\delta}\tilde{v}_{it-1}^2\right)^2\right]$$

Under the null hypothesis result indicate (Levin, Lin and Chu (2002)) that the regression t - statistics has a standard normal limiting distribution in model 1 but diverges to negative infinity for models 2 and 3.

The adjusted t statistics is

$$t_\delta^* = \frac{t_\delta - N\tilde{T}\hat{S}_N \hat{\sigma}_{\tilde{\varepsilon}}^{-2} STD(\hat{\delta})\mu_{m\tilde{T}}^*}{\sigma_{m\tilde{T}}^*}$$

$\mu_{m\tilde{T}}^*$ and $\sigma_{m\tilde{T}}^*$ are adjustment terms for the mean and the standard deviation

Details of Levin Lin and Chu (2002) unit root processes can be found from their original paper.

4.2 Tests with individual Unit root processes

We consider three tests that allow for individual unit root processes.

4.2.1 Im, Pesaran and Shin

Im, Pesaran and Shin (2003) (IPS here after) begin by specifying a separate ADF regression for each cross section with individual effect and no time trend.

Suppose that y_{it} are generated according to the following finite-order AR$(P_i + 1)$ processes:

$$y_{it} = \mu_i\phi_i(1) + \sum_{j=1}^{P_i+1} \phi_{ij} y_{i,t-j} + \varepsilon_{it}, \qquad i = 1,..,N, \qquad t = 1,..,T.$$

where $\phi_i(1) = 1 - \sum_{j=1}^{P_i+1}\phi_{ij}$, which can be written equivalently as the ADF (P_i) regressions:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{P_i} \rho_{ij}\Delta y_{i,t-j} + \varepsilon_{it}, \qquad i = 1,..,N, \qquad t = 1,\ldots,T.$$

where $\alpha_i = \mu_i\phi_i(1)$, $\beta_i = -\phi_i(1)$ and $\rho_{ij} = -\sum_{h=j+1}^{P_i+1}\phi_{ih}$

The null hypothesis may be written as,

$$H_0: \beta_i = 0, for\ all\ i$$

while the alternative hypothesis is given by:

$$H_1: \beta_i < 0, for\ i = 1,2, \dots, N_1\ , \beta_i = 0\ for\ i = N_1 + 1, N_1 + 2, \dots \dots, N.$$

For testing $\beta_i = 0$, the t-bar statistics is formed as a simple average of individual t statistics.

$$\overline{t_{NT}} = \frac{1}{N}\sum_{i=1}^{N} t_{iT}(P_i, \rho_i)$$

The t-bar is then standardized and IPS shows that when N and $T \rightarrow \infty$ then the standardized t bar statistic converges to the standard normal distribution. Their (IPS) proposed alternative standardized t bar statistic is

$$W_{\overline{t(P,\rho)}} = \frac{\sqrt{\mathrm{N}}\left\{\overline{t_{NT}} - \frac{1}{N}\sum_{i=1}^{N} E\{t_{\mathrm{i}T}(P_i, 0)|\beta_i = 0\}\right\}}{\sqrt{\frac{1}{\mathrm{N}}\sum_{\mathrm{i=1}}^{\mathrm{N}} Var\{\mathrm{t}_{\mathrm{i}T}(P_i, 0)|\beta_i = 0\}}}$$

$W_{\overline{t(P,\rho)}}$ converges in distribution to a standard normal variate sequentially, as $T \rightarrow \infty$ first and then $N \rightarrow \infty$.

$E\{t_{\mathrm{i}T}(P_i, 0)|\beta_i = 0\}$ and $\mathrm{Var}\{\mathrm{t}_{\mathrm{i}T}(P_i, 0)|\beta_i = 0\}$, are provided by IPS for various values of T and P. Details of the whole procedure can be found from IPS (2002) original paper.

4.2.2 Fisher-ADF and Fisher-PP

Augmented Dickey Fuller (1984) unit root test:
Let us consider the p th order autoregressive process,

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_{p-2} y_{t-p+2} + a_{p-1} y_{t-p+1} + a_p y_{t-p} + \varepsilon_t$$

adding and subtracting $a_p y_{t-p+1}$ to obtain

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_{p-2} y_{t-p+2} + (a_{p-1} + a_p) y_{t-p+1} - a_p \Delta y_{t-p+1} + \varepsilon_t$$

next, adding and subtracting $(a_{p-1} + a_p) y_{t-p+2}$ to obtain

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots - (a_{p-1} + a_p) \Delta y_{t-p+2} - a_p \Delta y_{t-p+1} + \varepsilon_t$$

Continuing in this fashion, we obtain

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta\, y_{t-i+1} + \varepsilon_t$$

where $\gamma = -\left(1 - \sum_{i=1}^{p} a_i\right)$ and $\beta_i = -\sum_{j=i}^{p} a_j$, for $i = 1,2, \dots, p - 1$.

The null and alternative hypotheses of the Augumented Dickey-Fuller t-test are

$$H_o: \gamma = 0$$
$$H_1: \gamma < 0$$

We can test for the presence of a unit root using the Dickey-Fuller t-test

$$t_{\hat{\gamma}} = \frac{\hat{\gamma} - 1}{Se(\hat{\gamma})}$$

This statistic does not follow the conventional student’s t-distribution. Critical values are calculated by Dickey and Fuller and depend on whether there is an intercept, deterministic trend or intercept and deterministic trend.

Phillips-Perron (1988) unit root test:
Phillips and Perron (1988) (PP here after) proposed nonparametric transformation of the t- statistics from the original DF regressions such that under the unit root null, the transformed statistics (the "Z" statistics) have DF distribution.
The test regression for the PP test is

$$\Delta y_t = \beta' D_t + \pi y_{t-1} + \mu_t$$

where μ_t is $I(0)$ may be heteroskedastic. The PP tests correct for any serial correlation and heteroskedasticity in the errors u_t of the test regression by directly modifying the test statistics $t_{\pi=0}$ and $\hat{\pi}$. These modified statistics, denoted Z_t and Z_π are given by

$$Z_t = \left(\frac{\hat{\sigma}^2}{\hat{\lambda}^2}\right)^{1/2} . t_{\pi=0} - \frac{1}{2}\left(\frac{\hat{\lambda}^2 - \hat{\sigma}^2}{\hat{\lambda}^2}\right) . \left(\frac{T.SE(\hat{\pi})}{\hat{\sigma}^2}\right)$$

$$Z_\pi = T_{\hat{\pi}} - \frac{1}{2}\frac{T^2.SE(\hat{\pi})}{\hat{\sigma}^2}(\hat{\lambda}^2 - \hat{\sigma}^2)$$

The terms $\hat{\sigma}^2$ and $\hat{\lambda}^2$ are consistent estimates of the variance parameters

$$\sigma^2 = \lim_{T\to\infty} T^{-1} \sum_{t=1}^{T} E[\mu_t^2]$$

$$\lambda^2 = \lim_{T\to\infty} \sum_{t=1}^{T} E[T^{-1} S_T^2]$$

$$S_T = \sum_{t=1}^{T} \mu_t .$$

The sample variance of the least squares residual $\hat{\mu}_t$ is a consistent estimate of σ^2, and the Newey-West long-run variance estimate of μ_t using $\hat{\mu}_t$ is a consistent estimate of λ^2.
Under the null hypothesis that $\pi = 0$, the Z_t and Z_π statistics have the same asymptotic distributions as the ADF t-statistics and normalized bias statistics. One advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error term μ_t. Another advantage is that it does not need to specify a lag length for the test regression.
Details of the PP test procedure can be found from their original paper.

Now to test the Fisher-ADF and Fisher PP- panel unit root tests, the approach is to uses Fisher's (1932) results to derive tests that combine the *p*-values from individual unit root tests.

If we define π_i $(i = 1,2, \dots, N)$ as the *p*-value from the i th individual unit root test and $-2log_e\pi_i$ has a χ^2distribution with 2 degree of freedom and $\Phi^{-1}(\pi_i)$ is distributed as $N(0,1)$. Here Φ^{-1} is the inverse of the standard normal cumulative distribution function.

Hence, under the null hypothesis of unit root for all N cross-sections, using the additive property,

$$P = - \ 2 \sum_{i=1}^{N} log_e(\pi_i) \tag{4.3}$$

is distributed as χ^2_{2N}, and

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1}(\pi_i) \tag{4.4}$$

is distributed as $N(0,1)$.

The combination of individual tests according to Fisher's suggestion (4.3) has among others been considered by Maddala and Wu (1999) and Choi (2001) also consider the combination of the individual tests according to (4.4).

If the individual unit root tests are augumended Dickey-Fuller tests (ADF) then the combined test performed according to (4.3) is referred to as Fisher-ADF test in reports from EViews. If instead the individual tests are Phillips-Perron test of unit root (PP), then the combine test perform according to (4.3) is referred to as Fisher-PP test in the report from EViews.

5 Panel Cointegration Details

For the analysis we use three types of panel cointegration test. One type of tests was introduced by Pedroni (1999) and a second type was introduced by Kao (1999) which is Engle-Granger (1987) two step residual based test, and a third type of tests was introduce by Fisher which a combined Johansen test.

5.1 Pedroni residual based panel cointegration

Pedroni (1999) derives seven panel cointegration test statistics. Of these seven statistics, four are based on within-dimension, and three are based on between-dimension. For the within-dimension statistics the null hypothesis of no cointegration for the panel cointegration test is

$$H_0: \gamma_i = 1 \; for \; all \; i$$
$$H_0: \gamma_i = \gamma < 1 \; for \; all \; i$$

For the between-dimension statistics the null hypothesis of no cointegration for the panel cointegration test is

$$H_0: \gamma_i = 1 \; for \; all \; i$$
$$H_0: \gamma_i < 1 \; for \; all \; i$$

First we compute the regression residuals from the hypothesized cointegration regression. In the most general case, this may take the from

$$y_{i,t} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \cdots + \beta_{Mi} x_{Mi,t} + e_{i,t} \qquad t = 1, ..T; i = 1, \dots N \qquad (5.1)$$

where T refers to the number of observation over time, N refers to the number of the individual members in the panel, and M refers to the number of regression variables. Here x and y are assumed to be integrated of order one. The slope coefficients $\beta_{1i}, \beta_{2i,} \dots, \beta_{Mi}$ and specific intercept α_i vary across individual member of the panel.

To estimate the residuals from equation (5.1), the seven Pedroni's statistics are:

1. Panel v-statistics: $T^2 N^{3/2} Z_{\hat{v}_{N,T}} \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i.t-1}^2 \right)^{-1}$
2. Panel ρ-Statistics: $T\sqrt{N} Z_{\hat{\rho}_{N,T^{-1}}} \equiv T\sqrt{N} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right)$
3. Panel t-Statistics: $Z_{t_{N,T}} \equiv \left(\tilde{\sigma}_{N,T}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right)$ (Non parametric)
4. Panel t-Statistics: $Z_{t_{N,T}}^* \equiv \left(\tilde{s}_{N,T}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^{*2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^* \Delta \hat{e}_{i,t}^*$ (Parametric)
5. Group ρ-Statistics:$TN^{-1/2} \tilde{Z}_{\hat{\rho}_{N,T^{-1}}} \equiv TN^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{e}_{i,t-1}^2 \right)^{-1} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right)$
6. Group t-Statistics: $N^{-1/2} \tilde{Z}_{t_{N,T}} \equiv N^{-1/2} \sum_{i=1}^{N} \left(\hat{\sigma}_i^2 \sum_{t=1}^{T} \hat{e}_{i,t-1}^2 \right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right)$ (Non-parametric)
7. Group t-Statistics: $N^{-1/2} \tilde{Z}_{t_{N,T}}^* \equiv N^{-1/2} \sum_{i=1}^{N} \left(\hat{s}_i^{*2} \sum_{t=1}^{T} \hat{e}_{i,t-1}^{*2} \right)^{-1} \sum_{t=1}^{T} \hat{e}_{i,t-1}^* \Delta \hat{e}_{i,t}^*$ (Parametric)

Where

$\hat{\lambda}_i = \frac{1}{T}\sum_{s=1}^{k_i}\left(1-\frac{s}{k_i+1}\right)\sum_{t=s+1}^{T}\hat{\mu}_{i,t}\hat{\mu}_{i,t-s}$, $\hat{s}_i^2 \equiv \frac{1}{T}\sum_{t=1}^{T}\hat{\mu}_{i,t}^2$, $\hat{\sigma}_i^2 = \hat{s}_i^2 + 2\hat{\lambda}_i$, $\tilde{\sigma}_{N,T}^2 \equiv \frac{1}{N}\sum_{i=1}^{N}\hat{L}_{11i}^{-2}\hat{\sigma}_i^2$

$$\hat{s}_i^{*2} \equiv \frac{1}{t}\sum_{t=1}^{T}\hat{\mu}_{i,t}^{*2},\ \tilde{s}_{N,T}^{*2} \equiv \frac{1}{N}\sum_{i=1}^{N}\hat{s}_i^{*2}\ ,\hat{L}_{11i}^{-2} = \frac{1}{T}\sum_{T}^{1}\hat{\eta}_{i,t}^2 + \frac{2}{T}\sum_{s=1}^{k_i}\left(1-\frac{s}{k_i+1}\right)\sum_{t=s+1}^{T}\hat{\eta}_{i,t}\hat{\eta}_{i,t-s}$$

and where the residual $\hat{u}_{i,t}$, $\hat{\mu}_{i,t}^*$, $\hat{\eta}_{i,t}$ are obtained from the following regressions:

$\hat{e}_{i,t} = \hat{\gamma}_i\hat{e}_{i,t-1} + \hat{u}_{i,t}$, $\hat{e}_{i,t} = \hat{\gamma}_i\hat{e}_{i,t-1} + \sum_{k=1}^{K_i}\hat{\rho}_{i,k}\Delta\hat{e}_{i,t-k} + \hat{\mu}_{i,t}^*$,$\Delta y_{i,t} = \sum_{m=1}^{M}\hat{b}_{mi}\Delta x_{mi,t} + \hat{\eta}_{i,t}$

Notes: All statistics are from Pedroni (1997a)

The first four statistics are within-dimension based statistics and the rest are between-dimension based statistics. In his paper Pedroni (1999) describe the seven test statistics, "The first of the simple panel cointegration statistics is a type of non-parametric variance ratio statistics. The second is a panel version of a non-parametric statistics that is analogous to the familiar Phillips Perron rho-statistics. The third statistics is also non-parametric and is analogous to the Phillips and Perron t-Statistics. The fourth statistics is the simple panel cointegration statistics which is corresponding to augmented Dickey-Fuller t-statistics."(Pedroni, 1999, p 658) "The rest of the statistics are based on a group mean approach. The first of these is analogous to the Phillips and Perron rho-statistics, and the last two analogous to the Phillips and Perron t-statistics and the augmented Dickey-Fuller t-statistics respectively" (Pedroni, 1999, p 658).

To compute any of these desired statistics in his paper Pedroni (1999) write a short summary.

"

1. Estimate the panel cointegration regression from equation (5.1), make sure to include any desired intercepts, time trends or common time dummies in the regression and collect the residuals $\hat{e}_{i,t}$for later use.
2. Difference the original series for each member, and compute the residual for the differenced regression $\Delta y_{i,t} = \beta_{1i}\Delta x_{1i,t} + \beta_{2i}\Delta x_{2i,t} + \cdots + \beta_{Mi}\Delta x_{Mi,t} + \eta_{i,t}$
3. Calculate $\hat{L}_{11i}^2$ as the long-run variance of $\hat{\eta}_{i,t}$ using any Kernel estimator such as the Newey-West (1987) estimator.
4. Using the residuals $\hat{e}_{i,t}$ of the original cointegration regression, estimate the appropriate autoregression, choosing either of the following from (a) or (b):

   (a)For the non-parametric statistics all except number four and number seven estimate $\hat{e}_{i,t} = \hat{\gamma}_i\hat{e}_{i,t-1} + \hat{u}_{i,t}$, and use the residuals to compute the long-run variance of $\hat{u}_{i,t}$, denoted $\hat{\sigma}_i^2$.

   (b) For the parametric statistics number four and seven estimate $\hat{e}_{i,t} = \hat{\gamma}_i\hat{e}_{i,t-1} + \sum_{k=1}^{K_i}\hat{\rho}_{i,k}\Delta\hat{e}_{i,t-k} + \hat{\mu}_{i,t}^*$ and use the residuals to compute the simple variance of $\hat{\mu}_{i,t}^*$, denoted $\hat{s}_i^{*2}$." (Pedroni, 1999, p 659)

After the calculation of the panel cointegration test statistics, Pedroni shows that the standardized statistic is asymptotically normally distributed

$$\frac{\aleph_{N,T} - \mu\sqrt{N}}{\sqrt{\upsilon}} \xrightarrow{d} N(0,1)$$

where $\aleph_{N,T}$ is the standardized form of the test statistics with respect to N and T. Here μ and υ are Monte Carlo generated adjustment terms.

5.2 Kao (1999) Cointegration Tests

In his paper Kao (1999) describes two tests under the null hypothesis of no cointegration for panel data. One is a Dickey-Fuller type test and another is an Augmented Dickey-Fuller type test. For the Dickey-Fuller type test Kao presents two sets of specification.

In the bivariate case Kao consider the following model

$$y_{it} = \alpha_i + \beta x_{it} + e_{it}, \qquad i = 1, .. N, t = 1, ... T$$

where

$$y_{it} = y_{it-1} + u_{it}$$

$$x_{it} = x_{it-1} + \varepsilon_{it}$$

α_i are the fixed effect varying across the cross-section observations, β is the slope parameter, y_{it} and x_{it} are independent random walks for all i .The residual series e_{it} should be I(1) series.
Now Kao define a long run covariance matrix of $w_{it} = (u_{it}, \varepsilon_{it})'$ is given by

$$\Omega = \lim_{T\to\infty} \frac{1}{T} E\left(\sum_{t=1}^{T} w_{it}\right)\left(\sum_{t=1}^{T} w_{it}\right)' = \Sigma + \Gamma + \Gamma' \equiv \begin{bmatrix} \sigma_{0u}^2 & \sigma_{0u\varepsilon} \\ \sigma_{0u\varepsilon} & \sigma_{0\varepsilon}^2 \end{bmatrix},$$

where

$$\Gamma = \lim_{T\to\infty} \frac{1}{T} \sum_{k=1}^{T-1} \sum_{t=k+1}^{T} E\,(w_{it} w'_{it-k}) \equiv \begin{bmatrix} \Gamma_u & \Gamma_{\varepsilon u} \\ \Gamma_{\varepsilon u} & \Gamma_u \end{bmatrix}$$

and

$$\Sigma = \lim_{T\to\infty} \frac{1}{T} \sum_{t=1}^{T} E(w_{it} w'_{it}) \equiv \begin{bmatrix} \sigma_u^2 & \sigma_{u\varepsilon} \\ \sigma_{u\varepsilon} & \sigma_\varepsilon^2 \end{bmatrix}$$

The Dickey-Fuller test can be applied to the estimated residual using

$$\hat{e}_{it} = \rho \hat{e}_{it-1} + v_{it}$$

Now the null and alternative hypothesis may be written as

$$H_0: \rho = 1$$
$$H_1: \rho < 1$$

The OLS estimate of ρ is given by

$$\hat{\rho} = \frac{\sum_{i=1}^{N} \sum_{t=2}^{T} \hat{e}_{it} \hat{e}_{it-1}}{\sum_{i=1}^{N} \sum_{t=2}^{T} \hat{e}_{it-1}^2}$$

Further calculation for Dickey-Fuller, Kao shows the following statistics

$$DF^*{}_\rho = \frac{\sqrt{N}\,T(\hat{\rho} - 1) + 3\sqrt{N}\hat{\sigma}^2{}_v / \hat{\sigma}^2{}_{0v}}{\sqrt{3 + 36\hat{\sigma}^4{}_v / (\hat{\sigma}^4{}_{0v})}} \sim N(0,1)$$

$$DF^*{}_t = \frac{t_\rho + \sqrt{6N}\hat{\sigma}_v / (2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}^2{}_{0v} / (2\hat{\sigma}^2{}_v) + 3\hat{\sigma}^2{}_v / (10\hat{\sigma}^2{}_{0v})}} \sim N(0,1)$$

where $t_\rho = \frac{(\hat{\rho}-1)\sqrt{\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{e}_{it-1}^{*2}}}{s_e}$, $s_e^2 = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=2}^{T}(\hat{e}_{it}^* - \rho\hat{e}_{it-1}^*)^2$, $\hat{e}_{it}^* = y_{it}^* - \hat{\alpha}_i^* - \hat{\beta}^* x_{it}^*$,
$\hat{\beta}^* = \frac{1}{N}\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{1}{T^2}(x_{it}^* - \bar{x}_i^*)^2$

In the case of strong exogeneity and no serial correlation ($\sigma_u^2 = \sigma_{0u}^2 = \sigma_v^2 = \sigma_{0v}^2$), the test statistics become

$$DF_\rho = \frac{T\sqrt{N}(\hat{\rho}-1)+3\sqrt{N}}{\sqrt{10.2}} \sim N(0,1)$$

$$DF_t = \sqrt{1.25}t_\rho + \sqrt{1.875N} \sim N(0,1)$$

These tests do not required estimate of the long-run variance-covariance matrix.
For the Augmented Dickey-Fuller test, estimated residual is

$$\hat{e}_{it} = \rho\hat{e}_{it-1} + \sum_{j=1}^{p} \varphi_j \, \Delta\hat{e}_{\mathrm{it-j}} + v_{itp}$$

Under the null of no cointegration, the ADF test take the from

$$t_{ADF} = \frac{(\hat{\rho}-1)\left[\sum_{i=1}^{N}(e_i' Q_i e_i)\right]^{\frac{1}{2}}}{s_v}$$

Further calculation Kao shows the following statistics

$$ADF = \frac{t_{ADF} + \sqrt{6N}\hat{\sigma}_v/(2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}^2{}_{0v}/(2\hat{\sigma}^2{}_v) + 3\hat{\sigma}^2{}_v/(10\hat{\sigma}^2{}_{0v})}} \sim N(0,1)$$

For estimation of long run parameter when we obtain the estimates of w_{it} and $\widehat{w}_{it}$ then we get,

$$\hat{\Sigma} = \begin{bmatrix} \hat{\sigma}^2{}_u & \hat{\sigma}_{u\varepsilon} \\ \hat{\sigma}_{u\varepsilon} & \hat{\sigma}^2{}_\epsilon \end{bmatrix} = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T} \widehat{\omega}_{it}\,\widehat{\omega}_{it}'$$

and

$$\widehat{\Omega} = \begin{bmatrix} \hat{\sigma}^2{}_{0u} & \hat{\sigma}_{0u\varepsilon} \\ \hat{\sigma}_{0u\varepsilon} & \hat{\sigma}^2{}_{0\epsilon} \end{bmatrix} = \frac{1}{NT}\sum_{i=1}^{N}\left[\frac{1}{T}\sum_{t=1}^{T}\widehat{\omega}_{it}\widehat{\omega}_{it}' + \frac{1}{T}\sum_{\mathcal{T}=1}^{l}\varpi_{\mathcal{T}l}\sum_{t=\mathcal{T}+1}^{T}\left(\widehat{\omega_{it}\widehat{\omega}_{it-\mathcal{T}}' + \widehat{\omega}_{it-\mathcal{T}}\widehat{\omega}_{it}'}\right)\right]$$

where $\varpi_{\mathcal{T}l}$ is a weight function or a kernel.
Details of Kao (1999) cointegration test procedure can be found in his original paper.

5.3 Combined Individual Tests (Fisher/Johansen)

Johansen Cointegration test:
Johansen (1988) proposes two different approaches, one of them is the likelihood ratio trace statistics and the other one is maximum eigenvalue statistics, to determine the presence of cointegration vectors in non stationary time series. The trace statistics and maximum eigenvalue statistics have shown in equation (5.2) and (5.3) respectively.

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{n} ln\left(1-\hat{\lambda}_i\right) \tag{5.2}$$

and

$$\lambda_{max}(r, r+1) = -Tln\left(1-\hat{\lambda}_{r+1}\right) \tag{5.3}$$

Here T is the sample size, n =3 variables real M3, real GDP and opportunity cost and $\hat{\lambda}_i$ is the i th largest canonical correlation between residuals from the three dimensional processes and residual from the three dimensional differentiate processes.
For the trace test tests the null hypothesis of at most r cointegration vector against the alternative hypothesis of full rank $r = n$ cointegration vector, the null and alternative hypothesis of maximum eigenvalue statistics is to check the r cointegrating vectors against the alternative hypothesis of $r + 1$ cointegrating vectors.

Using Johansens (1988) test for cointegration, Maddala and Wu (1999) consider Fisher's (1932) suggestion to combine individuals tests, to propose an alternative to the two previous tests, for testing for cointegration in the full panel by combining individual cross-sections tests for cointegration.

If π_i is the *p*-value from an individual cointegration test for cross-section i, then under the null hypothesis for the whole panel,

$$-2 \sum_{i=1}^{N} \log_{e} (\pi_i)$$

is distributed as χ^2_{2N}

EViews reports χ^2-value based on MacKinnon-Haug-Michelis (1999) p-values for Johansen's cointegration trace test and maximum eigenvalue test.

6 Results

To check the stationarity of our data we use the two types of panel unit root tests. As common unit root process we use Levin, Lin and Chu panel unit root test and for individual unit root process we use three type of panel unit root tests, first one is Im, Pesaran and Shin panel unit root test, second is Fisher type test, the ADF-Fisher chi-square test and last one is also a fisher type test, the PP-Fisher Chi square panel unit root test.

Table 2: Result of panel Unit root tests.

Variable	Levin Lin &Chu P-value**	Im, Pesaran and Shin P-value**	ADF-Fisher chi-square P-value**	PP-Fisher Chi-square P-value**
Real M3	0.5720	1.000	1.000	1.000
Δ Real M3	0.0000	0.000	0.000	0.000
Real GDP	0.9969	0.8529	0.2331	0.6833
ΔReal GDP	0.000	0.000	0.000	0.000
Deposit rate	0.0002	0.0011	0.0001	0.9682
ΔDeposit rate	0.000	0.000	0.000	0.000
LTGB	0.8989	0.7634	0.9721	0.7811
ΔLTGB	0.000	0.000	0.000	0.000
Diff	1.000	0.0809	0.3140	0.9856
ΔDiff	0.000	0.000	0.000	0.000

Null: Unit root
Levin Lin & Chu Test: Assumes common unit root process
Im, Pesaran and Shin: Assumes individual unit root process
ADF-Fisher chi-square: Assumes individual unit root process

PP-Fisher chi-square: Assumes individual unit root process
** Probabilities for fisher tests are computed using an asymptotic chi-Square distribution.
Exogenous variable: Individual effect
Automatic lag length selection based on SIC
Note: LTGB=long term government bond

In case of Real M3, Real GDP, Long term government bond (LTGB) and Difference between long term and short term Interest rate, the result shows that at 5% level of significance we accept null hypothesis that means the series are not stationary. After taking the first difference at 5% level of significance we reject null hypothesis, so first difference of the series is stationary. In case of deposit rate series in every test except PP-Fisher chi-square at 5% level of significance it reject null hypothesis but PP-Fisher chi-square accept null hypothesis it seems that the series has a unit root. But first difference of the series at 5% level of significance in all case reject null hypothesis. So after taking first difference the series is stationary. Details of the panel unit root test results of different variables, and also after taking first difference of different variables, are given in the appendix.

Then secondly we check the panel co-integration test on the basis of Driscoll (2004) money demand model for different opportunity cost (Deposit interest rate, Long term government bond and spread between long term and short term interest rate). At 5% level of significance, the Pedroni residual cointegration test, Johansen Fisher panel cointegration test and Kao residual cointegration test reject the null hypothesis which means there is a long run relationship exists within the variables. Details results are given in appendix.

Table 3: Pedroni Residual cointegration test

Series	Panel v-statistic		Panel rho-statistic		Panel pp-statistic		Panel ADF-statistics	
	Statistic	Prob	Statistic	Prob	Statistic	Prob	Statistic	Prob
Real M3, Real GDP, Deposit rate	6.24	0.00	-12.25	0.00	-9.26	0.00	-7.75	0.00
Real M3, Real GDP, LTIR	0.89	0.18	-9.93	0.00	-8.11	0.00	-5.71	0.00
Real M3, Real GDP, Diff	0.24	0.40	-10.21	0.00	-8.33	0.00	-5.02	0.00

Series	Group rho-Statistics		Group PP-Statistics		Group ADF-Statistics	
	Statistic	Prob	Statistic	Prob	Statistic	Prob
Real M3, Real GDP, Deposit rate	-11.9954	0.000	-12.4862	0.000	-8.6586	0.000
Real M3, Real GDP, LTIR	-9.1058	0.000	-9.7556	0.000	-5.1813	0.000
Real M3, Real GDP, Diff	-9.7613	0.000	-10.4716	0.000	-4.8026	0.000

Null Hypothesis: No cointegration
Trend Assumption: No deterministic intercept or trend
Automatic lag length selection based on SIC

From Table 3 in every case of opportunity cost except in panel v-statistics long term and difference between long term and short term at 5% level of significance, accept the null hypothesis otherwise in all case at 5% level of significance we reject the null hypothesis of no cointegration. This means the variable has a long run relationship.

Table 4: Kao Residual cointegration test

Series	ADF	
	t-statistics	Prob
Real M3, Real GDP, Deposit rate	-7.480519	0.000
Real M3, Real GDP, LTIR	-9.6022	0.000
Real M3, Real GDP, Diff	-9.9911	0.000

Null Hypothesis: No cointegration

Trend Assumption: No deterministic trend
Automatic lag length selection based on SIC
Note: ADF= Augmented Dickey-Fuller, DF=Dickey-Fuller

From Table 4 Kao Residual Cointegration test also shows us for every case of opportunity cost at 5% level of significance we reject null hypothesis of no cointegration and every case p-value 0.00 which is highly significance its gives a strong evidence that the variables has a long run relationship.

Table 5: Johansen Fisher panel cointegration test:

Series	No of CE(s)	Fisher Stat*(From trace test)	Prob	Fisher Stat*(From max-eigen test)	Prob
Real M3, Real GDP, Deposit rate	At most 2	87.27	0.000	87.27	0.000
Real M3, Real GDP, LTIR	At most 2	80.80	0.000	80.80	0.000
Real M3, Real GDP, Diff	At most 2	88.72	0.000	88.72	0.000

Trend assumption: No deterministic trend
*Probabilities are computed using asymptotic chi-square distribution.

In Table 5 we see for different opportunity cost in both case of Fisher trace test and Fisher max-eigen test at most 2 variables has a long run relationship. Details are given in appendix.

7 Conclusions

The aim of this paper is to check the Discroll (2004) money demand model in the context of the euro area. The main variables of this model are real M3, real GDP and opportunity cost. Three different types of opportunity costs are uses in this model. For eleven countries (which are the founding members of EMU since 1999) quarterly data were collected from Eurostat and OECD website. In a panel frame work unit root test shows that the first difference of all the series are stationary. Using Pedroni, Kao and Johansen Fisher panel cointegration test for three different opportunity cost, the test result give strong evidence that the variables has long run equilibrium.

References

Choi, I. (2001), “Unit Root Tests for Panel Data”, Journal of International Money and Finance, 20, 249-272.

Dickey, D. and Fuller, W. (1979), “Distribution of the Estimators for Autoregressive Time Series with a Unit Root”, Journal of the American Statistical Association, 74, 427-431.

Driscoll, J. C. (2004), “Does Bank Lending affect Output? Evidence from the U.S. States”, Journal of Monetary Economics 51(3), 451-471.

Enders, W. (2004), “Applied Econometric Time Series”, (second edition) Wiley & Sons.

Im, K. S., Pesaran, M. and Shin, Y. (2003), “Testing for Unit Roots in Heterogeneous Panels”, Journal of Econometrics 115, 53-74.

Johansen, S. (1988), “Statistical Analysis of Cointegration Vectors”, Journal of Economic and Control 12, 231-254.

Kao, C. (1999), “Spurious regression and residual-based tests for cointegration in panel data”, Journal of Econometrics 90, 1–44.

Levin, A., Lin, F. and Chu, CJ. (2002), “Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties”, Journal of Econometrics 108, 1–24.

MacKinnon, J. G., Haug, A. A. and Michelis, L. (1999), “ Numerical Distribution Functions of Likelihood Ratio Tests for Co-integration”, Journal of Applied Econometrics 14, 563-577.

Maddala, G. S. and Wu, S. (1999), “A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test”, Oxford Bulletin of Economics and Statistics 61, 631–652.

Mulligan, C. and Sala-i Martin, X. (1992), “U.S. money demand: Surprising cross-sectional estimates”, Brookings Papers on Economic Activity 2, 285-343.

Nautz, D. and Randorf, U. (2010), “The (In)stability of Money Demand in the Euro Area: Lessons from Cross-Country Analysis”, SFB 649 Discussion Paper 2010-023.

Pedroni, P. (1997a), “Panel Cointegration ; Asymptotic and Finite Sample Properties of Pooled time Series Tests, With an Application to The PPP Hypothesis: New Results”, Indiana University Working Papers In Economics.

Pedroni, P. (1999), “Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors”, Oxford Bulletin of Economics and Statistics 61, 653-670.

Pedroni, P. (2004), “Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis”, Econometric Theory 20, 579-625.

Pesaran, M. H. (2007), “A Simple Panel Unit Root Test in the Presence of Cross Section Dependence”, Journal of Applied Econometrics 22, 265-312.

Phillips, P.C.B. and Perron, P. (1988), “Testing for Unit Roots in Time Series Regression”, Biometrika, 75, 335-346.

Said, S.E. and Dickey, D. (1984), “Testing for Unit Roots in Autoregressive Moving-Average Models with Unknown Order”, Biometrika,71, 599-607.

Setzer, R. and Wolff , G. (2009), “Money demand in the euro area: New insights from disaggregated data”, EU Commission, Economic Papers (373).

Appendix

Unit root test of Real M3

Panel unit root test: Summary
Series: RM3
Date: 08/04/10 Time: 12:43
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	0.18151	0.5720	11	460
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	4.53547	1.0000	11	460
ADF - Fisher Chi-square	3.91416	1.0000	11	460
PP - Fisher Chi-square	3.92439	1.0000	11	462

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

1st difference

Panel unit root test: Summary
Series: D(RM3)
Date: 08/04/10 Time: 12:44
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-14.0373	0.0000	11	451
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-15.6843	0.0000	11	451
ADF - Fisher Chi-square	233.863	0.0000	11	451
PP - Fisher Chi-square	238.388	0.0000	11	451

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Unit root test of Real gdp

Panel unit root test: Summary
Series: LNRGDPSA
Date: 08/04/10 Time: 12:48
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	2.73666	0.9969	11	447
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	1.04900	0.8529	11	447
ADF - Fisher Chi-square	26.4431	0.2331	11	447
PP - Fisher Chi-	18.3788	0.6833	11	462

1st difference

Panel unit root test: Summary
Series: D(LNRGDPSA)
Date: 08/04/10 Time: 12:48
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 4
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-9.15491	0.0000	11	444
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-12.4918	0.0000	11	444
ADF - Fisher Chi-square	177.526	0.0000	11	444
PP - Fisher Chi-	186.362	0.0000	11	451

square

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

square

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Unit root test of deposit interest rate

	1st difference

Panel unit root test: Summary
Series: LNDEPOSIT_RATE
Date: 08/04/10 Time: 12:50
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.59533	0.0002	11	438
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-3.05073	0.0011	11	438
ADF - Fisher Chi-square	57.3934	0.0001	11	438
PP - Fisher Chi-square	11.4212	0.9682	11	462

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

1st difference

Panel unit root test: Summary
Series: D(LNDEPOSIT_RATE)
Date: 08/04/10 Time: 12:52
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-9.36245	0.0000	11	441
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-10.5539	0.0000	11	441
ADF - Fisher Chi-square	155.156	0.0000	11	441
PP - Fisher Chi-square	177.117	0.0000	11	451

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Unit root test of long term government bond interest rate

	1st difference

Panel unit root test: Summary
Series: LNLTIR
Date: 08/04/10 Time: 12:54
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				

1st difference

Panel unit root test: Summary
Series: D(LNLTIR)
Date: 08/04/10 Time: 12:55
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				

Levin, Lin & Chu t*	1.27528	0.8989	11	461
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.71719	0.7634	11	461
ADF - Fisher Chi-square	11.1779	0.9721	11	461
PP - Fisher Chi-square	16.6734	0.7811	11	462

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Levin, Lin & Chu t*	-12.4449	0.0000	11	450
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-12.5536	0.0000	11	450
ADF - Fisher Chi-square	178.879	0.0000	11	450
PP - Fisher Chi-square	173.622	0.0000	11	451

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Unit root test of spread between long term and short term interest rate

Panel unit root test: Summary
Series: DIFF
Date: 08/04/10 Time: 12:57
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	5.43435	1.0000	11	451
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.39883	0.0809	11	451
ADF - Fisher Chi-square	24.6512	0.3140	11	451
PP - Fisher Chi-square	10.0791	0.9856	11	462

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

1st difference

Panel unit root test: Summary
Series: D(DIFF)
Date: 08/04/10 Time: 12:58
Sample: 1999Q1 2009Q3
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-4.07520	0.0000	11	451
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-5.76391	0.0000	11	451
ADF - Fisher Chi-square	71.7885	0.0000	11	451
PP - Fisher Chi-square	74.4492	0.0000	11	451

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Panel cointegration test of real m3 real gdp and deposit rate

Pedroni residual cointegration test

Pedroni Residual Cointegration Test
Series: DRM3 DLNRGDPSA DLNDEPOSIT_RATE
Date: 08/04/10 Time: 13:37
Sample: 1999Q1 2009Q3
Included observations: 473
Cross-sections included: 11
Null Hypothesis: No cointegration
Trend assumption: No deterministic intercept or trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	6.247074	0.0000	0.328691	0.3712
Panel rho-Statistic	-12.25592	0.0000	-9.826451	0.0000
Panel PP-Statistic	-9.264065	0.0000	-8.479211	0.0000
Panel ADF-Statistic	-7.755713	0.0000	-7.236247	0.0000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	-11.99545	0.0000
Group PP-Statistic	-12.48624	0.0000
Group ADF-Statistic	-8.658624	0.0000

Cross section specific results

Phillips-Peron results (non-parametric)

Cross ID	AR(1)	Variance	HAC	Bandwidth	Obs
Austria	0.282	0.000260	0.000274	3.00	41
Belgium	0.488	0.000176	0.000192	4.00	41
Finland	0.316	0.000579	0.000581	9.00	41
France	0.305	0.000272	0.000335	3.00	41
Germany	0.516	0.000133	0.000119	1.00	41
Ireland	0.098	0.001200	0.001747	4.00	41
Italy	0.115	0.000793	0.000986	4.00	41
Luxembourg	0.383	0.000523	0.000494	3.00	41
Netherlands	0.201	0.000526	0.000628	3.00	41
Portugal	-0.088	0.000133	0.000133	0.00	41
Spain	0.286	0.000102	0.000107	2.00	41

Augmented Dickey-Fuller results (parametric)

Cross ID	AR(1)	Variance	Lag	Max lag	Obs
Austria	0.282	0.000260	0	9	41
Belgium	0.840	8.15E-05	2	9	39
Finland	0.316	0.000579	0	9	41
France	0.618	0.000224	1	9	40

Johansen Fisher panel cointegration test

Johansen Fisher Panel Cointegration Test
Series: DRM3 DLNRGDPSA DLNDEPOSIT_RATE
Date: 08/04/10 Time: 13:39
Sample: 1999Q1 2009Q3
Included observations: 473
Trend assumption: No deterministic trend
Lags interval (in first differences): 1 1

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	202.4	0.0000	125.3	0.0000
At most 1	115.5	0.0000	72.83	0.0000
At most 2	87.27	0.0000	87.27	0.0000

* Probabilities are computed using asymptotic Chi-square distribution.

Individual cross section results

Cross Section	Trace Test Statistics	Prob.**	Max-Eign Test Statistics	Prob.**
Hypothesis of no cointegration				
Austria	50.3139	0.0000	30.6812	0.0004
Belgium	42.0460	0.0001	27.9510	0.0011
Finland	52.1922	0.0000	28.5412	0.0008
France	31.8002	0.0047	18.9364	0.0336
Germany	37.2847	0.0007	19.9281	0.0235
Ireland	37.8550	0.0006	26.6750	0.0018
Italy	37.6125	0.0006	22.4964	0.0091
Luxembourg	67.0258	0.0000	37.1068	0.0000
Netherlands	34.3697	0.0019	17.0916	0.0636
Portugal	49.5770	0.0000	28.1876	0.0010
Spain	29.2447	0.0109	16.0134	0.0909
Hypothesis of at most 1 cointegration relationship				
Austria	19.6328	0.0025	14.2585	0.0142
Belgium	14.0950	0.0250	10.1018	0.0783
Finland	23.6510	0.0004	15.8449	0.0072
France	12.8638	0.0405	8.0353	0.1722
Germany	17.3566	0.0066	10.7193	0.0613
Ireland	11.1800	0.0770	8.2181	0.1610
Italy	15.1161	0.0166	12.7335	0.0270
Luxembourg	29.9190	0.0000	17.7335	0.0032
Netherlands	17.2780	0.0068	10.6448	0.0631
Portugal	21.3894	0.0012	12.9307	0.0248
Spain	13.2313	0.0351	9.9467	0.0832

Germany	0.516	0.000133	0	9	41
Ireland	0.098	0.001200	0	9	41
Italy	0.115	0.000793	0	9	41
Luxembourg	0.383	0.000523	0	9	41
Netherlands	0.444	0.000483	1	9	40
Portugal	- 0.088	0.000133	0	9	41
Spain	0.434	0.000100	1	9	40

Hypothesis of at most 2 cointegration relationship

Austria	5.3743	0.0243	5.3743	0.0243
Belgium	3.9932	0.0542	3.9932	0.0542
Finland	7.8061	0.0062	7.8061	0.0062
France	4.8285	0.0332	4.8285	0.0332
Germany	6.6374	0.0119	6.6374	0.0119
Ireland	2.9619	0.1009	2.9619	0.1009
Italy	2.3827	0.1449	2.3827	0.1449
Luxembourg	12.1855	0.0006	12.1855	0.0006
Netherlands	6.6332	0.0119	6.6332	0.0119
Portugal	8.4587	0.0043	8.4587	0.0043
Spain	3.2846	0.0828	3.2846	0.0828

**MacKinnon-Haug-Michelis (1999) p-values

Kao residual cointegration Test

Kao Residual Cointegration Test
Series: DRM3 DLNRGDPSA DLNDEPOSIT_RATE
Date: 08/04/10 Time: 13:42
Sample: 1999Q1 2009Q3
Included observations: 473
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	-7.480519	0.0000

Residual variance	0.000718
HAC variance	0.000110

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID)
Method: Least Squares
Date: 08/04/10 Time: 13:42
Sample (adjusted): 1999Q3 2009Q3
Included observations: 451 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.959208	0.047850	-20.04613	0.0000

R-squared	0.471718	Mean dependent var	-0.000160
Adjusted R-squared	0.471718	S.D. dependent var	0.026855
S.E. of regression	0.019519	Akaike info criterion	-5.032649
Sum squared resid	0.171445	Schwarz criterion	-5.023533
Log likelihood	1135.862	Hannan-Quinn criter.	-5.029056
Durbin-Watson stat	1.970450		

Panel cointegration test of real m3 real gdp and long term interest rate

Pedroni residual cointegration test

Pedroni Residual Cointegration Test
Series: DRM3 DLNRGDPSA DLNLTIR
Date: 08/04/10 Time: 13:50
Sample: 1999Q1 2009Q3
Included observations: 473
Cross-sections included: 11
Null Hypothesis: No cointegration
Trend assumption: No deterministic intercept or trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	0.891282	0.1864	-0.242740	0.5959
Panel rho-Statistic	-9.933183	0.0000	-8.732225	0.0000
Panel PP-Statistic	-8.111433	0.0000	-7.697432	0.0000
Panel ADF-Statistic	-5.718900	0.0000	-5.567922	0.0000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	-9.105846	0.0000
Group PP-Statistic	-9.755656	0.0000
Group ADF-Statistic	-5.181384	0.0000

Cross section specific results

Phillips-Peron results (non-parametric)

Cross ID	AR(1)	Variance	HAC	Bandwidth	Obs
Austria	0.550	0.000380	0.000372	3.00	41
Belgium	0.462	0.000189	0.000220	4.00	41
Finland	0.259	0.000789	0.000815	6.00	41
France	0.554	0.000298	0.000284	3.00	41
Germany	0.654	0.000170	0.000150	2.00	41
Ireland	0.383	0.001225	0.001532	4.00	41
Italy	0.139	0.000837	0.000922	3.00	41
Luxembourg	0.234	0.000896	0.000987	3.00	41
Netherlands	0.172	0.000659	0.000792	3.00	41
Portugal	-0.019	0.000473	0.000579	3.00	41
Spain	0.772	0.000137	0.000101	1.00	41

Augmented Dickey-Fuller results (parametric)

Cross ID	AR(1)	Variance	Lag	Max lag	Obs
Austria	0.550	0.000380	0	9	41
Belgium	0.832	9.23E-05	2	9	39
Finland	0.259	0.000789	0	9	41
France	0.768	0.000236	1	9	40

Johansen Fisher panel cointegration test

Johansen Fisher Panel Cointegration Test
Series: DRM3 DLNRGDPSA DLNLTIR
Date: 08/04/10 Time: 13:53
Sample: 1999Q1 2009Q3
Included observations: 473
Trend assumption: No deterministic trend
Lags interval (in first differences): 1 1

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	229.6	0.0000	141.9	0.0000
At most 1	126.1	0.0000	88.78	0.0000
At most 2	80.80	0.0000	80.80	0.0000

* Probabilities are computed using asymptotic Chi-square distribution.

Individual cross section results

Cross Section	Trace Test Statistics	Prob.**	Max-Eign Test Statistics	Prob.**
Hypothesis of no cointegration				
Austria	45.7587	0.0000	27.6380	0.0012
Belgium	49.6076	0.0000	28.9183	0.0007
Finland	43.4320	0.0001	22.7977	0.0081
France	35.6180	0.0012	23.2452	0.0069
Germany	42.5527	0.0001	25.7636	0.0026
Ireland	46.8164	0.0000	23.0543	0.0074
Italy	42.9100	0.0001	27.4357	0.0013
Luxembourg	61.3996	0.0000	32.8040	0.0001
Netherlands	47.0137	0.0000	30.2965	0.0004
Portugal	48.1419	0.0000	27.1768	0.0015
Spain	41.9452	0.0001	27.3394	0.0014
Hypothesis of at most 1 cointegration relationship				
Austria	18.1207	0.0048	11.6477	0.0421
Belgium	20.6894	0.0016	16.1665	0.0063
Finland	20.6344	0.0016	15.3267	0.0090
France	12.3729	0.0490	8.5696	0.1412
Germany	16.7891	0.0084	9.8373	0.0868
Ireland	23.7621	0.0004	19.2751	0.0016
Italy	15.4742	0.0143	12.6687	0.0277
Luxembourg	28.5956	0.0001	21.1712	0.0007
Netherlands	16.7173	0.0086	11.2517	0.0494
Portugal	20.9651	0.0014	12.8115	0.0261
Spain	14.6058	0.0204	11.4529	0.0456

Germany	0.654	0.000170	0	9	41
Ireland	0.721	0.000968	2	9	39
Italy	0.139	0.000837	0	9	41
Luxembourg	0.234	0.000896	0	9	41
Netherlands	0.754	0.000443	4	9	37
Portugal	-0.019	0.000473	0	9	41
Spain	0.851	0.000121	1	9	40

Hypothesis of at most 2 cointegration relationship				
Austria	6.4730	0.0130	6.4730	0.0130
Belgium	4.5229	0.0397	4.5229	0.0397
Finland	5.3077	0.0252	5.3077	0.0252
France	3.8033	0.0607	3.8033	0.0607
Germany	6.9518	0.0099	6.9518	0.0099
Ireland	4.4870	0.0405	4.4870	0.0405
Italy	2.8056	0.1111	2.8056	0.1111
Luxembourg	7.4244	0.0076	7.4244	0.0076
Netherlands	5.4656	0.0230	5.4656	0.0230
Portugal	8.1537	0.0051	8.1537	0.0051
Spain	3.1529	0.0898	3.1529	0.0898

**MacKinnon-Haug-Michelis (1999) p-values

Kao residual cointegration test

Kao Residual Cointegration Test
Series: DRM3 DLNRGDPSA DLNLTIR
Date: 08/04/10 Time: 13:55
Sample: 1999Q1 2009Q3
Included observations: 473
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	-9.602259	0.0000
Residual variance	0.000847	
HAC variance	0.000188	

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID)
Method: Least Squares
Date: 08/04/10 Time: 13:55
Sample (adjusted): 1999Q3 2009Q3
Included observations: 451 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.946902	0.047845	-19.79094	0.0000

R-squared	0.465276	Mean dependent var	-0.000357
Adjusted R-squared	0.465276	S.D. dependent var	0.029259
S.E. of regression	0.021396	Akaike info criterion	-4.849045
Sum squared resid	0.205998	Schwarz criterion	-4.839928
Log likelihood	1094.460	Hannan-Quinn criter.	-4.845452
Durbin-Watson stat	1.991535		

Panel cointegration test of real m3 real gdp and spread between long term and short term interest rate

Pedroni residual cointegration test

Pedroni Residual Cointegration Test
Series: DRM3 DLNRGDPSA DDIFF
Date: 08/04/10 Time: 13:58
Sample: 1999Q1 2009Q3
Included observations: 473
Cross-sections included: 11
Null Hypothesis: No cointegration
Trend assumption: No deterministic intercept or trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	0.246848	0.4025	-0.338702	0.6326
Panel rho-Statistic	-10.21582	0.0000	-9.947180	0.0000
Panel PP-Statistic	-8.333442	0.0000	-8.339810	0.0000
Panel ADF-Statistic	-5.028812	0.0000	-5.108242	0.0000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	-9.761307	0.0000
Group PP-Statistic	-10.47165	0.0000
Group ADF-Statistic	-4.802659	0.0000

Cross section specific results

Phillips-Peron results (non-parametric)

Cross ID	AR(1)	Variance	HAC	Bandwidth	Obs
Austria	0.519	0.000405	0.000440	4.00	41
Belgium	0.444	0.000187	0.000228	4.00	41
Finland	0.294	0.000760	0.000727	5.00	41
France	0.513	0.000277	0.000317	4.00	41
Germany	0.671	0.000147	0.000147	0.00	41
Ireland	0.385	0.001223	0.001518	4.00	41
Italy	0.119	0.000838	0.000806	2.00	41
Luxembourg	0.207	0.000820	0.000862	2.00	41
Netherlands	0.136	0.000648	0.000908	4.00	41
Portugal	0.007	0.000476	0.000585	3.00	41
Spain	0.707	0.000150	0.000150	0.00	41

Augmented Dickey-Fuller results (parametric)

Cross ID	AR(1)	Variance	Lag	Max lag	Obs
Austria	0.519	0.000405	0	9	41
Belgium	0.813	9.10E-05	2	9	39
Finland	0.294	0.000760	0	9	41
France	0.715	0.000225	1	9	40

Johansen Fisher panel cointegration test

Johansen Fisher Panel Cointegration Test
Series: DRM3 DLNRGDPSA DDIFF
Date: 08/04/10 Time: 13:58
Sample: 1999Q1 2009Q3
Included observations: 473
Trend assumption: No deterministic trend
Lags interval (in first differences): 1 1

Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	219.4	0.0000	144.5	0.0000
At most 1	113.1	0.0000	70.07	0.0000
At most 2	88.72	0.0000	88.72	0.0000

* Probabilities are computed using asymptotic Chi-square distribution.

Individual cross section results

Cross Section	Trace Test Statistics	Prob.**	Max-Eign Test Statistics	Prob.**
Hypothesis of no cointegration				
Austria	52.2997	0.0000	38.5410	0.0000
Belgium	49.8475	0.0000	34.0296	0.0001
Finland	54.3408	0.0000	30.1431	0.0004
France	42.8024	0.0001	27.2605	0.0014
Germany	38.5393	0.0004	22.5964	0.0088
Ireland	43.0394	0.0001	28.3491	0.0009
Italy	51.4707	0.0000	27.1724	0.0015
Luxembourg	50.1673	0.0000	34.4311	0.0001
Netherlands	34.9079	0.0016	16.5255	0.0768
Portugal	35.7884	0.0012	14.6756	0.1388
Spain	37.8353	0.0006	23.9361	0.0053
Hypothesis of at most 1 cointegration relationship				
Austria	13.7587	0.0285	8.5072	0.1446
Belgium	15.8179	0.0125	9.8754	0.0855
Finland	24.1978	0.0003	15.1105	0.0099
France	15.5419	0.0139	10.9024	0.0569
Germany	15.9429	0.0119	10.2580	0.0736
Ireland	14.6903	0.0197	10.7454	0.0606
Italy	24.2983	0.0003	19.6138	0.0014
Luxembourg	15.7363	0.0129	11.3906	0.0468
Netherlands	18.3824	0.0043	10.2742	0.0731

Germany	0.671	0.000147	0	9	41
Ireland	0.713	0.000983	2	9	39
Italy	0.119	0.000838	0	9	41
Luxembourg	0.370	0.000738	2	9	39
Netherlands	0.752	0.000424	4	9	37
Portugal	0.007	0.000476	0	9	41
Spain	0.804	0.000121	1	9	40

Portugal	21.1129	0.0013	10.8457	0.0583
Spain	13.8993	0.0270	10.3403	0.0713
Hypothesis of at most 2 cointegration relationship				
Austria	5.2515	0.0260	5.2515	0.0260
Belgium	5.9426	0.0176	5.9426	0.0176
Finland	9.0873	0.0030	9.0873	0.0030
France	4.6395	0.0371	4.6395	0.0371
Germany	5.6850	0.0203	5.6850	0.0203
Ireland	3.9449	0.0558	3.9449	0.0558
Italy	4.6845	0.0361	4.6845	0.0361
Luxembourg	4.3456	0.0440	4.3456	0.0440
Netherlands	8.1081	0.0052	8.1081	0.0052
Portugal	10.2672	0.0016	10.2672	0.0016
Spain	3.5590	0.0702	3.5590	0.0702

**MacKinnon-Haug-Michelis (1999) p-values

Kao residual cointegration test

Kao Residual Cointegration Test
Series: DRM3 DLNRGDPSA DDIFF
Date: 08/04/10 Time: 13:59
Sample: 1999Q1 2009Q3
Included observations: 473
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	-9.991103	0.0000
Residual variance	0.000851	
HAC variance	0.000189	

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID)
Method: Least Squares
Date: 08/04/10 Time: 13:59
Sample (adjusted): 1999Q3 2009Q3
Included observations: 451 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.965043	0.047678	-20.24100	0.0000

R-squared	0.476527	Mean dependent var	-0.000234
Adjusted R-squared	0.476527	S.D. dependent var	0.029205
S.E. of regression	0.021130	Akaike info criterion	-4.874024
Sum squared resid	0.200916	Schwarz criterion	-4.864907
Log likelihood	1100.092	Hannan-Quinn criter.	-4.870431
Durbin-Watson stat	1.995729		