COINTEGRATION ANALYSIS OF GERMAN AND BRITISH TOURISM DEMAND FOR GREECE

Dr. Nikolaos Dritsakis
Associate Professor
University of Macedonia
Economics and Social Sciences
Department of Applied Informatics
156 Egnatia Street
P.O box 1591
540 06 Thessaloniki, Greece
FAX: (031) 891290
e-mail: drits@.uom.gr
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Abstract

Germany and Great Britain are traditionally two of the most important sources of tourism for Greece. The purpose of this paper is to investigate changes in the long-run demand for tourism to Greece by these two countries. In order to explain the demand for tourism, we are using a number of leading macroeconomic variables, including income in origin countries (Germany and Great Britain), tourism prices in Greece, and transportation cost and exchanges rates between the three countries. Annual data from the three countries, covering the period from 1960 to 2000, are employed. Augmented Dickey-Fuller test for unit root is examined in the univariate framework and Johansen’s maximum likelihood procedure is used to test the cointegration method and to estimate the number of cointegrating vectors of VAR model. Error correction models are estimated to explain German and British demand for tourism to Greece.

Keywords: tourism demand, cointegration analysis, error correction model,

1. Introduction

Tourism is an important source of income for many countries - especially for those with less developed modern service/industrial based economies. The economic benefits accruing to both the producers of tourist products and the
tourist originating economy in local, regional and national level have been the subject of extensive studies by both tourism experts and multidisciplinary scholars.

Tourist destinations have an *a priori* concentration of tourism related “raw materials”. In this case raw materials refer mainly to a combination of natural and man-made elements that are related closely with tourism demand and, unlike other aspects of economic activity, are unique to the tourism destination and therefore cannot be transferred to or recreated at another location. It is well known that natural and climatic factors play the primary role in choosing a holiday destination. However, apart from favourable natural and climatic factors, man-made factors – such as culture, heritage or results of human activity- also play an important role in the decision for a tourist destination that can be supplementary to or independent of the “raw materials” in the destination (Dritsakis 1995, Seddighi *et al* 2001, Seddighi and Theocharous 2002).

The existence of favourable natural and climatic conditions in a country or (and) rich cultural evidence does not automatically guarantee its choice as a popular tourist destination. It must first ensure that a minimum level of tourism provision is in place, such as adequate infrastructure and, most important, a reasonably priced tourist product.

Due to its unique combination of both the aforementioned factors, Greece is a popular tourist destination with most of the European countries. Germany and Great Britain are the major originators of tourists for Greece.

Over the period 1960-2000, total tourist arrivals to Greece grew at an average rate of 2.4% per annum. Tourist arrivals from Europe form the main part of foreign visitors in Greece. Germany is the most important source of tourists for
Greece and over the examined period had an average annual growth rate of tourist arrivals to Greece 3.2% per annum. The average annual growth rate of tourist arrivals from Great Britain (the second biggest source of tourists), was 3.1% per annum for the same period.

In this paper a cointegration analysis of multivariate time series is presented, where some time series are modelled simultaneously and we have a priori knowledge for the expected signs of the variables examined. Economic variables such as income, tourism prices, cost of transportation and exchange rates are examined in order to explain tourist arrivals from Germany and Great Britain to Greece.

Many time series models like Box-Jenkins ARIMA model that do not have explicit economic context but arise empirically, are used to explain the level of tourist arrivals (Johnson and Ashworth 1990, Morley 1992, Syriopoulos 1995, Lim 1997, Lim and McAller 2000a, 2000b). The changes in tourist arrivals are exclusively related to their past levels or are time-dependent. Nevertheless, the econometric models that explain the structure of tourist arrivals by a specific origin country can also combine present and past values of the other economic variables with tourist arrivals (Witt and Witt 1995, Song and Witt 2000, Dritsakis and Athanasiadis 2000).

The rest of the paper is organized as follows: section 2 describes the data used for the tourism demand analysis for Greece. Section 3 describes the results of the unit root test. Section 4 briefly outlines the cointegration analysis and Johansen’s test for cointegration. Section 5 presents the empirical results of tourism demand to Greece from Germany and Great Britain. Section 6 discusses the error
correction models for travel to Greece from Germany and Great Britain. Finally, section 7 presents some conclusive remarks.

2. Data

In the analysis of tourism demand to Greece from Germany and Great Britain the following function is used:

\[ AR = F(Y, TP, TR, ER) \]  

(1)

where (AR) expresses tourist arrivals from every origin country, (Y) the real income per capita, (TP) tourism prices, (TR) transportation cost, (ER) exchange rates between the origin and destination countries’ currencies. The sample period under consideration is 1960 to 2000. All variables are expressed in logarithms to capture multiplicative time series effects and are denoted with letter L preceding each variable name.

Data real income variables include real Gross Domestic Product (GDP) per capita, real private consumption expenditure per capita, real private expenditure on consumption services per capita at 1990 prices.

Tourism prices, which include the cost of goods and services purchased by tourists in the destination country, are measured by relative prices or real exchange rates (Witt and Martin 1987, Dritsakis and Gialitaki 2001). The relative price variable is given by the indicative ratio of the consumer price indices (CPI) of the destination country to the origin countries. The logarithm of relative prices (LTP) indicates the difference between the logarithm of prices level in Greece and origin countries for the examined period in this paper.
The average economy class airfare prices of different airport companies from the origin country to Athens are used as proxies for transportation costs of the two origin countries of tourists. (These data have been obtained from the Greek national carrier, Olympic Airways).

The real exchange rate measures the effective prices of goods and services in destination country, when consumer price index adjusts between the exchange rates differences in currencies of origin and destination countries. Nominal exchange rate $ER$ is expressed by the number of units of origin country’s currency that are needed for the purchase of one drachma. The real exchange rate is given by the logarithm of prices level in Greece minus the logarithm of prices level in origin countries minus the logarithm of exchange rate.

$$LTP = \log \left[ \frac{CPI(GR)}{CPI(Origin)} \right] = \log CPI(GR) - \log CPI(Origin)$$

$$LER = \log \left[ \frac{CPI(GR)}{CPI(Origin)} \cdot \frac{1}{ER} \right] = \log CPI(GR) - \log CPI(Origin) - \log ER$$

where $ER =$ the exchange rates in units of origin country’s currency that are needed for the purchase of one drachma

Data sources include the National Statistical Service of Greece, IMF International Financial Statistics, the World Bank, the Bank of Greece and databases of Datastream and EconData.

Although marketing spending and special promotions are expected to play an important role in attracting tourists from these two countries to Greece, there is no appropriate information for the expenditure involved in each country.
The Greek Tourism Organization is responsible for Greece’s tourism marketing strategy and spending in all European countries. Unfortunately the breakdown of the total promotional expenditure per country is not available.

The list of variables used in the analysis of German and British tourism demand for Greece is as follows:

LAR = Logarithm of tourist arrivals from an origin country to Greece.
LY = Logarithm of real gross domestic product per capita.
LTP = Logarithm of relative prices (tourism prices).
LTR = Logarithm of real airfares prices in the origin country’s currency (transportation cost).
LER = Logarithm of real exchange rate or exchange rate of adjusted relative prices.

The examination of variables’ plots suggests that tourist arrivals, real income per capita, tourism prices, transportation costs, and real exchange rates appear to be non-stationary and contain a predetermined stochastic trend. This means that these specific variables contain important information to explain the changes in tourist arrivals to Greece. In the underlying economic framework, the demand for international travels is positively related to income in the origin countries, and negatively related to tourism prices, transportation costs and real exchange rates of the origin country. The variables may drift apart in the short-run but should move together in the long-run.

If these variables share a common stochastic trend, their first differences are stationary and consequently may be jointly cointegrated. Economic theory does not often provide guidance in determining which variables have stochastic trends, and when such trends are common among variables. For multivariate time series
analysis involving stochastic trends, augmented Dickey-Fuller unit root tests are calculated for individual time series to provide evidence as to whether the variables are integrated. This is followed by multivariate cointegration analysis.

3. Unit root test

Testing for cointegration among several variables that are used in the above model needs primarily a test for the presence of unit root for every individual variable, namely real tourism arrivals, gross domestic product, tourism prices, transportation costs, real exchange rates, using the Augmented Dickey-Fuller test (ADF) (1979) based on the auxiliary regression:

\[ \Delta y_t = \alpha + \delta t + \beta y_{t-1} + \sum_{i=1}^{k} \gamma \Delta y_{t-1} + u_t \]  \hspace{1cm} (2)

The ADF auxiliary regression tests for the existence of a unit root in \( y_t \), namely the logarithm of all model’s variables at time \( t \). The variable \( \Delta y_{t-1} \) expresses the lagged first differences, \( u_t \) adjusts the serial correlation errors and \( \alpha, \delta, \beta \) and \( \gamma \) are the parameters to be estimated. The null and alternative hypotheses for a unit root in variable \( y_t \) are:

\[ H_0 : \beta = 0 \hspace{1cm} H_e : \beta < 0 \]

The tests are performed sequentially. First, the ADF test is calculated for the sample period, with and without a deterministic trend. The time trend is included in the auxiliary regression equation if the reported ADF t-statistics show that the
regression is statistically significant. If time trend is not included in the examined variables, then the regression equation will reduce the power of the test. A sufficient number of lagged first differences are included to remove any serial correlation in the residuals. In order to determine k, an initial lag length of 4 is selected, and the fourth lag is tested for significance using the standard asymptotic t-ratio. If the fourth lag is insignificant, the lag length is reduced successively until a significant lag length is obtained. If no lagged first differences are used, the ADF test reduces to the Dickey-Fuller (DF) test. The MFIT 4.0 (1997) software package, which is used to conduct the ADF tests, reports the simulated critical values.

Table 1 presents the results of the ADF tests of real tourist arrivals, real income per capita, tourism prices, transportation costs and exchange rate for Germany. The ADF tests statistics are compared with the critical value from the non-standard Dickey-Fuller distribution with time trend at the 5% level significance. The calculated ADF statistics for all variables exceed the critical value. This means that none of all variables is stationary. Thus, the null hypothesis of a unit root is not rejected.

**Table 1**

Table 2 shows that, with the exception of LTP, taking first differences renders each series stationary, with the ADF statistics in all cases being less than the critical value at 5% level significance. The result for the variable LTP is sensitive to the choice of lag length. At the one lag, the null hypothesis of a unit root is still not rejected. However, at zero lags the null hypothesis of a unit root is rejected.

**Table 2**
The Akaike Information Criterion (AIC) (1973) and the Schwarz Bayesian Criterion (SBC) (1978) yield smaller values for one lag. By taking the second differences, LTP becomes a stationary time series. The ADF test for the individual series of Germany indicates that all variables are integrated order one I(1), apart from tourism prices (LTP) that are integrated with order two I(2). Therefore, tourism prices of Germany are not cointegrated with the other time series.

According to Table 3, the null hypothesis of a unit root test is not rejected for all variables for Great Britain. By taking first differences Table 4 shows that all time series become stationary as the ADF statistic for each time series (except LPT) is lower than the relative critical value at a 5% level significance. The variable LPT becomes stationary in second differences. From these results we can infer that all variables are integrated order 1 I(1), but tourism prices (LPT) are integrated order 2 I(2). Consequently, tourism prices of Great Britain are not cointegrated with the other time series.

4. Cointegration and Johansen test

If time series variables are nonstationary in their levels they are integrated (of order one) and their first differences are stationary. These variables may also be cointegrated if there exists one or more linear combinations among them that is
stationary. If these variables are cointegrated, then there is a stable long run or equilibrium linear relationship among them. For instance, if tourist travel demand as measured by tourist arrivals to a certain destination, and real income are not cointegrated, then the tourist arrivals would drift above or below income in the long-run. Granger (1986, p.226) argued that ‘A test for cointegration can thus be thought of as a pre-test to avoid ‘spurious regression’ situations’. Furthermore, Engle and Granger (1987, p.264) prescribed that ‘it may not be so easy to test whether a set of variables are cointegrated before estimating a multivariate dynamic model.’

Cointegration and error correction models are closely related. Engle and Granger (1987, p.254) defined error correction as ‘a proportion of the disequilibrium from one period is corrected in the next period’. An error correction model relates the change in one variable to past equilibrium errors.

If the hypothesis of a unit root is not rejected, then a test for cointegration is performed. The hypothesis being tested is the null of noncointegration against the alternative of cointegration, using Johansen’s maximum likelihood method. A vector autoregression approach is used to model each variable (which is assumed to be jointly endogenous) as a function of all the lagged endogenous variables in the system. Johansen (1988) considers a simple case where $X_t$ is integrated of order one, such that the first difference of $X_t$ is stationary.

Suppose the process $X_t$ is defined by an unrestricted VAR system of order $(n \times 1)$

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + u_t$$

(3)

where $X_t = (n \times 1)$ vector of I(1) variables

$\Pi_i = (n \times n)$ matrix of unknown parameters to be estimated ($i = 1, 2, 3, \ldots, k$).
\( u_t \) = independent and identically distributed \((n \times 1)\) vector of error terms.

\( t = 1, 2, 3 \ldots \) \(T\) observations

Using \( \Delta = (I - L) \), where \( L \) is the lags operator the system of above can be reparameterized in the error correction form as:

\[
\Delta X_t = \sum_{j=1}^{k-1} \Gamma_j \Delta X_{t-j} + \Pi X_{t-k} + u_t
\]

(4)

where \( \Delta X_t \) is an \( I(0) \) vector.

\( I \) is an \((n \times n)\) identity matrix

\[
\Gamma_j = \sum_{i=1}^{k-1} \Pi_j - I \quad \text{i} = 1, 2, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots k-1.
\]

and

\[
\Pi = \sum_{j=1}^{k} \Pi_j - I
\]

The above equation (4) is known as a vector error correction (VEC) model.

Johansen’s approach derives maximum likelihood estimators of the cointegrating vectors for an autoregressive process with independent errors. The \((n \times n)\) matrix \( \Pi \) can be written as the product of \( \alpha \) and \( \beta \), two \((n \times r)\) matrices each of rank \( r \), such that \( \Pi = \beta \alpha' \), where \( \alpha \) contains the \( r \) cointegrating vectors and \( \beta \) represents the matrix of weighting elements. Hence the above equation can be written as:

\[
\Delta X_t = \sum_{j=1}^{k-1} \Gamma_j \Delta X_{t-j} + (\beta \alpha') X_{t-k} + u_t
\]

The maximum likelihood approach enables testing the hypothesis of \( r \) cointegrating relations among the elements of \( X_t \).

\( \text{Ho} : \Pi = \beta \alpha' \)
where the null hypothesis of no cointegrating relations \( r = 0 \) implies \( \Pi = 0 \). Thus, test for cointegration test whether the eigenvalues of the estimated \( \Pi \) are significantly different from 0. This approach also tests for the number of cointegrating relations, where \( 0 \leq r < n \). If there is no cointegrating relation, then no linear combination of \( nI(1) \) variables is stationary.

Johansen’s method maximizes the likelihood function for \( X_t \), conditional on any given \( \alpha \), using standard least squares formulae for the regression of \( \Delta X_t \) on the lagged differences \( \Delta X_{t-1}, \Delta X_{t-2}, \ldots, \Delta X_{t-k+1} \) and \( \alpha \Gamma X_{t-k} \). This approach provides estimates of \( \Gamma_1, \Gamma_2, \ldots, \Gamma_{k-1} \) and \( \beta \), conditional on \( \alpha \) and can also be used to test which cointegrating vectors are statistically significant.

In the empirical section below, the number of cointegrating relations among the \( I(1) \) variables of the used model are presented.

5. Empirical results

Most variables that have been used in the model reported in the last section as tourist arrivals (LAR), real income per capita (LY), transportation cost (LTR), real exchange rate (LER) of demand for travel to Greece that come from Germany and Great Britain are integrated of order 1, \( I(1) \). Therefore, they can be cointegrated on a VAR model up to four lags. As the lag intervals are specified as range pairs, this means that lags of the first differences are used, the highest lag in their levels is order 5. Thus, if lag intervals 1 to 4 are chosen the VAR model applies the regression analysis \( \Delta Y_t \) on \( \Delta Y_{t-1}, \Delta Y_{t-2}, \Delta Y_{t-3}, \Delta Y_{t-4} \) and contain four variables. In implementing the Johansen procedure, a linear deterministic trend and intercept are included in the cointegrating equation.
The order of $r$ is determined by using the likelihood ratio (LR) trace test statistic suggested by Johansen (1988).

$$\lambda_{\text{trace}}(q,n) = -T \sum_{i=q+1}^{k} \ln(1 - \hat{\lambda}_i)$$  \hspace{1cm} (5)

for $r = 0, 1, 2, \ldots, k-1$, 

$T$ = the number of observation used for estimation

$\hat{\lambda}_i$ = is the $i$th largest estimated eigenvalue.

Critical values for the trace statistic defined by equation (5) are 58.93 and 55.01 for $H_0: r = 0$ and 39.33 and 36.28 for $H_0: r \leq 1$ at the significance level 5% and 10% respectively as reported by Osterwald-Lenum (1992).

The maximum eigenvalue LR test statistic as suggested by Johansen is:

$$\lambda_{\text{max}}(q, q+1) = -T\ln(1 - \hat{\lambda}_{q+1})$$  \hspace{1cm} (6)

The trace statistic either rejects the null hypothesis of no cointegration among the variables ($r=0$) or does not reject the null hypothesis that there is one cointegrating relation between the variables ($r \leq 1$). Tables 5 and 6 present the results for all systems of equations, each with one cointegrating relation, in which the coefficients of the variables are significant at the 5% level and have the correct signs. As AIC tends to select the larger lag length and SBC the more parsimonious VAR an LR test was used to select the appropriate lag length. The null hypothesis that a system is generated by a Gaussian VAR with $p_0$ lags, against the alternative specification of $p_1 > p_0$ is tested by the LR test statistic, which is computed as:

$$LR = -2(l_0 - l_i)$$

where $l_i$ ($i = 0, 1$) is the log-likelihood reported in the VAR model with $p_i$ ($i = 0, 1$) lags. Under $H_0$, the LR test statistic is asymptotically distributed as $X^2$, with
\( n^2(p_i - p_0) \) degrees of freedom. The null hypothesis imposes \( n^2(p_i - p_0) \) restrictions, where \( n = \) number of variables.

Based on the smallest AIC and SBC values, the trace test results for one cointegrating equation involving four variables are presented in Table 5 and 6. When normalized for a unit coefficient on tourist arrivals (LAR) the most appropriate cointegrating regression of the long-run demand for international travel by tourists that come from Germany and Great Britain respectively, is given by VAR(3) models as follows (with absolute asymptotic t-ratios in parentheses):

\[
LAR = -36.3465 + 2.1592 LY - 0.6155 LTR - 0.9881 LER \quad (7)
\]

\[
(\text{-6.3292}) \quad (\text{3.8956}) \quad (-6.4175) \quad (-2.6040)
\]

\[
LAR = 0.11357 + 6.0268 LY - 1.4031 LTR - 1.1990 LER \quad (8)
\]

\[
(\text{2.1694}) \quad (\text{7.3703}) \quad (-2.6412) \quad (-4.3809)
\]

The coefficient estimates in the equilibrium relation which are the estimated long-run elasticities with respect to tourist arrivals, show that real income per capita is elastic, while real costs (as measured by the logarithm of airfares) and real exchange rate are both inelastic for tourist arrivals from Germany, while all coefficients by their estimations in equilibrium relationship are elastic to tourist arrivals from Great Britain.
6. Error correction models

If \( u_{1t} \) and \( u_{2t} \) are the cointegrating residuals from each of equations 7 and 8, then these residuals should be included as an error correction term in an international tourism demand VAR model, where \( u_{1t} \) and \( u_{2t} \) can be interpreted as the extent to which the system is out of equilibrium. The equilibrium residuals for Germany and Great Britain are respectively:

\[
\begin{align*}
    u_{1t} &= LAR + 36.3465 - 2.1592 \, LY + 0.6155 \, LTR + 0.9881 \, LER \\
    u_{2t} &= LAR - 0.11357 + 6.0268 \, LY - 1.4031 \, LTR - 1.1990 \, LER
\end{align*}
\]  

Only at the zero lag length do the ADF test results indicate that the cointegrating residuals are an I(0) process. Given the low power of the unit root tests and the sensitivity related to the choice of lag length, inspection of the correlogram shows that the autocorrelation function for the cointegrating residuals dies off with increasing lag, which suggests a stationary process.

In order to estimate a dynamic international tourism demand VEC (Vector Error Correction) model using the Ordinary Least Squares method (OLS), the cointegrating vector should be included. Tourists’ arrivals can be expressed as:

\[
\Delta LAR_t = \mu + \Gamma_1 \Delta LAR_{t-1} + \Gamma_2 \Delta LY_{t-1} + \Gamma_3 \Delta LTR_{t-1} + \Gamma_4 \Delta ER_{t-1} + \lambda u_{t-1} + V_t
\]  

Tables 7 and 8 report the VEC model’s estimates for Germany and Great Britain. The VEC model’s specification forces the long-run behaviour of the
endogenous variables to converge to their cointegrating relationships, while accommodating short-run dynamics. The dynamic specification of the model suggests deleting the insignificant variables until a regression with all its coefficients statistically significant will be obtained.

INSERT TABLE 7 APPROXIMATELY HERE

INSERT TABLE 8 APPROXIMATELY HERE

A subset of the variables is tested for statistical significance to examine if they can be omitted from the model. The associated tests statistics reported include the F-statistic and the log-likelihood ratio statistic. Each of the insignificant variables is deleted sequentially from the general dynamic model, while the error correction model is retained, which is statistically significant at 5% level. The tests statistics do not reject the null hypothesis that the selected coefficients are jointly zero at the 5% significance level. By deleting the statistically insignificant regressors, Tables 9 and 10 are obtained with all variables statistically significant and the coefficients in error correction terms are negative and statistically significant as well. The estimated coefficients of error correction terms measure the speed of adjustment to restore equilibrium in the dynamic model. The negative sign of the estimated coefficients of income is explained by the fact that German and English tourists (with higher income level), may prefer other tourist destinations than Greece. For example they may prefer more developed tourist countries, some tourists prefer over Atlantic destinations in exotic countries and other tourists like travelling to more safe destinations. Political stability and suppression of terrorism are basic preconditions for the tourist's safety.
We also apply a number of diagnostic tests on the residuals of the model. We apply the Lagrange test (A) for the residuals’ autocorrelation, the Heteroscedasticity test (D) and the Bera-Jarque (C) normality test. We also test the functional form of the model according to the Ramsey’s Reset test. Chow’s first and second tests check the model’s predictive ability. Tables 9 and 10 indicate that all diagnostic tests are statistically significant for both countries in selected VEC models.

7. Conclusions

The relationships among the demand for travelling, income of origin country, tourism prices, transportation costs and exchange rates have received considerable attention in empirical tourism research (Dritsakis and Papanastasiou 1998, Lim 1999). Even though it is well known empirically that many macroeconomic time series are nonstationary, most published tourism research has estimated static models in logarithmic levels using ordinary least squares. This practice gives rise to invalid inferences, so there is little informational content in examining the alleged significance of the estimated coefficients.

Cointegration techniques permit the estimation and testing of the long-run equilibrium relationships, as suggested by economic theory. Vector error correction (VEC) models provide a way of combining both the dynamics of the short run (changes) and long-run (levels) adjustment processes simultaneously.
Using separate tourist arrivals data from Germany and Great Britain to Greece as measures of tourism demand from these countries, the long-run economic relationships among international tourism demand real income, transportation cost and exchange rates have been estimated. Prior to testing for cointegration among a set of variables, the ADF test of nonstationarity is performed to determine the order of integration of the individual time series. Johansen’s maximum likelihood procedure is used for estimation and testing of the cointegrating relations based on vector autoregressive models.

The methods used, and the results presented in this paper, provide some useful insights into the effects of income, tourism prices, transportation cost and exchange rate on international tourism demand to Greece from the two most important origin countries of Europe.

The existence of a long-run equilibrium relationship among international tourism demand, income, transportation cost and real exchange rate appear to be supported by the data used for the examined period. According to the theory of cointegration, the estimated cointegrating residual should appear as the error correction term in a dynamic VEC model. An important finding from the dynamic models presented is that the error correction terms are negative and statistically significant. All regressors in the VEC models are statistically significant, there is no evidence of any problems associated with serial correlation, functional form, normality, heteroscedasticity. Given a statistically significant error correction model in a dynamic VEC model, it can be interpreted as evidence supporting cointegration, which suggests the existence of an equilibrium long-run relationship among important economic variables determining international tourism demand.
References


### Table 1. Unit root test for Germany

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF lag length</th>
<th>ADF statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAR</td>
<td>1</td>
<td>-1.3846</td>
</tr>
<tr>
<td>LY</td>
<td>0</td>
<td>-1.5602</td>
</tr>
<tr>
<td>LTP</td>
<td>1</td>
<td>-2.0477</td>
</tr>
<tr>
<td>LTR</td>
<td>0</td>
<td>-2.6835</td>
</tr>
<tr>
<td>LER</td>
<td>0</td>
<td>-2.3040</td>
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</table>

95% critical value for the augmented D-F statistic = -3.5386

### Table 2. Unit root test of first differences for Germany

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF lag length</th>
<th>ADF statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAR</td>
<td>1</td>
<td>-4.9493</td>
</tr>
<tr>
<td>LY</td>
<td>2</td>
<td>-4.1312</td>
</tr>
<tr>
<td>LTP</td>
<td>1</td>
<td>-3.2376</td>
</tr>
<tr>
<td>LTR</td>
<td>2</td>
<td>-5.7354</td>
</tr>
<tr>
<td>LER</td>
<td>1</td>
<td>-5.4477</td>
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95% critical value for the augmented D-F statistic = -3.5426

### Table 3. Unit root test for Great Britain

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF lag length</th>
<th>ADF statistic</th>
</tr>
</thead>
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<tr>
<td>LTP</td>
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<td>-2.1006</td>
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<tr>
<td>LTR</td>
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<tr>
<td>LER</td>
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<td>-2.4111</td>
</tr>
</tbody>
</table>

95% critical value for the augmented D-F statistic = -3.5386

### Table 4. Unit root test of first differences for Great Britain

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF lag length</th>
<th>ADF statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAR</td>
<td>1</td>
<td>-5.1653</td>
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<tr>
<td>LY</td>
<td>1</td>
<td>-4.7245</td>
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<tr>
<td>LTP</td>
<td>1</td>
<td>-2.9412</td>
</tr>
<tr>
<td>LTR</td>
<td>1</td>
<td>-3.7744</td>
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<tr>
<td>LER</td>
<td>1</td>
<td>-4.1916</td>
</tr>
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</table>

95% critical value for the augmented D-F statistic = -3.5426
Table 5. Johansen and Juselious trace test for one Cointegration equation for Germany

<table>
<thead>
<tr>
<th>Trace Statistic</th>
<th>Critical Values</th>
</tr>
</thead>
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<td>Null</td>
<td>Alternative</td>
</tr>
<tr>
<td>$r = 0$</td>
<td>$r = 1$</td>
</tr>
<tr>
<td>$r \leq 1$</td>
<td>$r \geq 2$</td>
</tr>
</tbody>
</table>

Table 6. Johansen and Juselious trace test for one Cointegration equation for Great Britain

<table>
<thead>
<tr>
<th>Trace Statistic</th>
<th>Critical Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null</td>
<td>Alternative</td>
</tr>
<tr>
<td>$r = 0$</td>
<td>$r = 1$</td>
</tr>
<tr>
<td>$r \leq 1$</td>
<td>$r \geq 2$</td>
</tr>
</tbody>
</table>

Table 7. Estimates of the vector error correction model for Germany

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONST</td>
<td>0.1806</td>
<td>0.0518</td>
<td>3.4860 [.002]</td>
</tr>
<tr>
<td>ΔLARGER(-1)</td>
<td>0.1412</td>
<td>0.2149</td>
<td>0.6572 [.516]</td>
</tr>
<tr>
<td>ΔLARGER(-2)</td>
<td>0.0562</td>
<td>0.2083</td>
<td>0.2700 [.789]</td>
</tr>
<tr>
<td>ΔLYGER(-1)</td>
<td>-1.4247</td>
<td>1.0780</td>
<td>-1.3216 [.197]</td>
</tr>
<tr>
<td>ΔLYGER(-2)</td>
<td>-0.5819</td>
<td>1.0575</td>
<td>-0.5503 [.586]</td>
</tr>
<tr>
<td>ΔLTRGER(-1)</td>
<td>-5.6529</td>
<td>2.2556</td>
<td>-2.5062 [.018]</td>
</tr>
<tr>
<td>ΔLTRGER(-2)</td>
<td>-1.2056</td>
<td>2.1748</td>
<td>-0.5543 [.584]</td>
</tr>
<tr>
<td>ΔLERGER(-1)</td>
<td>0.2839</td>
<td>0.4462</td>
<td>0.6363 [.530]</td>
</tr>
<tr>
<td>ΔLERGER(-2)</td>
<td>-0.0870</td>
<td>0.4222</td>
<td>-0.2061 [.838]</td>
</tr>
<tr>
<td>U1(-1)</td>
<td>-0.5124</td>
<td>0.1902</td>
<td>-2.6934 [.012]</td>
</tr>
</tbody>
</table>
Table 8. Estimates of the vector error correction model for Great Britain

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONST</td>
<td>0.2545</td>
<td>0.0630</td>
<td>-4.0362 [.000]</td>
</tr>
<tr>
<td>ΔLARGB(-1)</td>
<td>-0.0663</td>
<td>0.1855</td>
<td>-0.3576 [.723]</td>
</tr>
<tr>
<td>ΔLARGB(-2)</td>
<td>-0.1517</td>
<td>0.1489</td>
<td>-1.0193 [.317]</td>
</tr>
<tr>
<td>ΔLYGB(-1)</td>
<td>-3.2778</td>
<td>1.2476</td>
<td>-2.6273 [.014]</td>
</tr>
<tr>
<td>ΔLYGB(-2)</td>
<td>-0.1038</td>
<td>1.3697</td>
<td>-0.0757 [.940]</td>
</tr>
<tr>
<td>ΔLTRGB(-1)</td>
<td>-0.5698</td>
<td>1.5848</td>
<td>-0.3595 [.722]</td>
</tr>
<tr>
<td>ΔLTRGB(-2)</td>
<td>-5.1126</td>
<td>1.9082</td>
<td>-2.6793 [.012]</td>
</tr>
<tr>
<td>ΔLERGB(-1)</td>
<td>-0.4917</td>
<td>0.3318</td>
<td>-1.4820 [.150]</td>
</tr>
<tr>
<td>ΔLERGB(-2)</td>
<td>0.0660</td>
<td>0.3803</td>
<td>0.1736 [.863]</td>
</tr>
<tr>
<td>U1(-1)</td>
<td>-0.3032</td>
<td>0.1347</td>
<td>-2.2512 [.032]</td>
</tr>
</tbody>
</table>

Table 9. Testing for the exclusion of variables for Germany

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONST</td>
<td>0.1602</td>
<td>0.0421</td>
<td>3.8049 [.001]</td>
</tr>
<tr>
<td>ΔLARGER(-1)</td>
<td>0.0740</td>
<td>0.2331</td>
<td>2.3175 [.053]</td>
</tr>
<tr>
<td>ΔLYGER(-1)</td>
<td>-1.1668</td>
<td>1.1141</td>
<td>-3.0473 [.005]</td>
</tr>
<tr>
<td>ΔLTRGER(-1)</td>
<td>4.4497</td>
<td>2.3387</td>
<td>-1.9026 [.069]</td>
</tr>
<tr>
<td>ΔLERGER(-1)</td>
<td>0.1039</td>
<td>0.5781</td>
<td>2.0198 [.059]</td>
</tr>
<tr>
<td>U1(-1)</td>
<td>-0.4605</td>
<td>0.2107</td>
<td>-2.1849 [.038]</td>
</tr>
</tbody>
</table>

\[ R^2 = 0.5675 \]
\[ F(5,25) = 4.8439 \ [0.041] \]
\[ DW = 2.2349 \]

Diagnostic Tests

A: \( X^2[1] = 3.7208 \) [0.054]  
B: \( X^2[1] = 2.7427 \) [0.098]  
C: \( X^2[2] = 14.7473 \) [0.010]  
D: \( X^2[1] = 0.5348 \) [0.465]  
E: \( X^2[7] = 1.4441 \) [0.984]  
F: \( X^2[6] = 1.0233 \) [0.985]
### Table 10. Testing for the exclusion of variables for Great Britain

Dependent variable is $\Delta LARGB$

31 observations used for estimation from 1963 to 1993

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio [Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONST</td>
<td>0.2413</td>
<td>0.0400</td>
<td>6.0290 [0.000]</td>
</tr>
<tr>
<td>$\Delta LARGB(-2)$</td>
<td>-0.2330</td>
<td>0.1409</td>
<td>-2.6528 [0.011]</td>
</tr>
<tr>
<td>$\Delta LYGB(-1)$</td>
<td>-2.8794</td>
<td>1.1086</td>
<td>-2.5973 [0.016]</td>
</tr>
<tr>
<td>$\Delta LTRGB(-2)$</td>
<td>-4.8279</td>
<td>1.7051</td>
<td>-2.8314 [0.009]</td>
</tr>
<tr>
<td>$\Delta LERGB(-1)$</td>
<td>-0.6351</td>
<td>0.3425</td>
<td>-1.8542 [0.076]</td>
</tr>
<tr>
<td>U1(-1)</td>
<td>-0.3700</td>
<td>0.1341</td>
<td>-2.7583 [0.011]</td>
</tr>
</tbody>
</table>

$\bar{R}^2 = 0.64249$  
$F(9,28) = 3.1414 [0.010]$  
$DW = 1.9172$

**Diagnostic Tests**

A: $X^2[1] = 0.14501 [0.703]$  
B: $X^2[1] = 4.8276 [0.028]$  
C: $X^2[2] = 1.2043 [0.548]$  
D: $X^2[1] = 0.7457 [0.388]$  
E: $X^2[7] = 10.094 [0.183]$  
F: $X^2[6] = 2.7381 [0.841]$

**Notes:**

$\Delta$: Denotes the first differences of the variables.

$\bar{R}^2 =$ Coefficient of multiple determination adjusted for the degrees of freedom (d.f).

$DW =$ Durbin-Watson statistic.

$F(n, m) =$ F-statistic with n,m d.f respectively.

A: $X^2(n)$ Lagrange multiplier test of residual serial correlation, following $x^2$ distribution with n d.f.

B: $X^2(n)$ Ramsey’s Reset test for the functional form of the model, following $x^2$ distribution with n d.f.

C: $X^2(n)$ Normality test based on a test of skewness and kurtosis of residuals, following $x^2$ distribution with n d.f.

D: $X^2(n)$ Heteroscedasticity test, following $x^2$ distribution with n d.f.

E: $X^2(n)$ Chow’s second test for predictive failure, following $x^2$ distribution with n d.f.

F: $X^2(n)$ Chow’s first test of stability of the regression coefficients, following $x^2$ distribution with n d.f.

( ) = We denote the t-ratio for the corresponding estimated regression coefficient.

[ ] = We denote prob. Levels.