Introduction to Modern Time Series Analysis

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**Teaching Material**

The following figures and tables are from the above book. They are provided to help instructors and students and may be used for teaching purposes as long as a reference to the book is given in class.

1 Introduction and Basics



*Figure 1.1: Real Gross Domestic Product of the Federal Republic   
of Germany in billions of Euro, 1960 – 2011*



*Figure 1.2: Quarterly Changes of the Real Gross Domestic Product (ΔGDP)  
of the Federal Republic of Germany, 1960 – 1989*



*Figure 1.3: Quarterly Growth Rates of the Real Gross Domestic Product (qgr)  
of the Federal Republic of Germany, 1960 – 1989*



*Figure 1.4: Annual Changes of the Real Gross Domestic Product (Δ4GDP) of the Federal Republic of Germany, 1961 – 1989*



*Figure 1.5: Annual Growth Rates of Real Gross Domestic Product (agr) of the Federal Republic of Germany, 1960 – 1989*



*Figure 1.6: ‘Smooth Component‘ and actual values of the Real Gross Domestic Product of the Federal Republic of Germany, 1961 – 2011*



*Figure 1.7: Example of a Random Walk where only the steps +1   
and –1 are possible*



*Figure 1.8: Exchange Rate Swiss Franc U.S. Dollar,   
Monthly data, January 1974 to December 2011*

2 Univariate Stationary Processes



*Figure 2.1: AR(1) process with α = 0.9*



##### Figure 2.2: AR(1) process with α= 0.5



*Figure 2.3: AR(1) process with α = -0.9*



*Figure 2.4: Popularity of the CDU/CSU, 1971 – 1982*

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*Figure 2.5: AR(2) process with α1 = 1.5, α2= -0.56*



*Figure 2.6: AR(2) process with α1 = 1.4 and α2 = -0.85*



*Figure 2.7: Three month money market rate in Frankfurt, 1970 – 1998*



*Figure 2.8: Estimated partial autocorrelation functions*

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| *Table 2.1:* *Characteristics of the Autocorrelation and the Partial Autocorrelation Functions of AR and MA Processes* | | |
|  | Autocorrelation Function | Partial Autocorrelation Function |
| MA(q) | breaks off with q | does not break off |
| AR(p) | does not break off | breaks off with p |



*Figure 2.9: Theoretical autocorrelation functions of ARMA(1,1) processes*



*Figure 2.10: Three month money market rate in New York, 1994 – 2003*

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| *Table 2.2:* *Forecasts of the Council of Economic Experts  and of the Economic Research Institutes* | | | | | | | |
|  | Period | R2 | RMSE | MAE | ME | â1 | U |
| Institutes | 1970 – 1995 | 0.369 | 1.838 | 1.346 | -0.250\* | 1.005\* | 0.572 |
| 1970 – 1982 | 0.429 | 2.291 | 1.654 | -0.731 | 1.193\* | 0.625 |
| 1983 – 1995 | 0.399 | 1.229 | 1.038 | 0.231 | 1.081 | 0.457 |
| Council of Economic Experts | 1970 – 1995 | 0.502\* | 1.647\* | 1.171\* | -0.256 | 1.114 | 0.512\* |
| 1970 – 1982 | 0.599\* | 2.025\* | 1.477\* | -0.723\* | 1.354 | 0.552\* |
| 1983 – 1995 | 0.472\* | 1.150\* | 0.865\* | 0.212\* | 1.036\* | 0.428\* |
| ‘\*’ denotes the ‘better’ of the two forecasts. | | | | | | | |

3 Granger Causality



*Figure 3.1: Growth rate of real GDP and the four quarters lagged interest rate spread in the Federal Republic of Germany, 1970 – 1989 (in percent)*

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| *Table 3.1*  *Test for Granger Causality (I): Direct Granger Procedure 1/65 – 4/89, 100 Observations* | | | | | | |
| y | x | k1 | k2 | F(y←x) | F(y→x) | F(y–x) |
| Δ4ln(GDPr)  Δ4ln(GDPr)  Δ4ln(M1r) | Δ4ln(M1r)  GLR – GSR  GLR – GSR | 4  8  4  8  4  8 | 4  8  4  8  4  8 | 6.087\*\*\*  3.561\*\*  3.160\*  1.927(\*)  5.615\*\*\*  2.521\* | 1.918  1.443  3.835\*\*  2.077\*  1.489  1.178 | 0.391  0.001  0.111  0.279  10.099\*\*  15.125\*\*\* |
| ‘(\*)’, ‘\*’, ‘\*\*’, or ‘\*\*\*’ denote that the null hypothesis that no causal relation exists can be rejected at the 10, 5, 1 or 0.1 percent significance level, respectively. | | | | | | |

*Figure 3.2*. (The dotted lines are the approximate 95 percent confidence intervals.)

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|  |  | k |

*Figure 3.2a: Cross-correlations between the residuals of the univariate models of GDP and the quantity of money M1*

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*Figure 3.2b: Cross-correlations between the residuals of the univariate models of GDP and the interest rate spread*

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*Figure 3.2c: Cross-correlations between the residuals of the univariate models of the quantity of money M1 and the interest rate differential*

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| *Table 3.2:* *Test for Granger Causality (II): Haugh-Pierce Test 1/65 – 4/89, 100 Observations* | | | | | | |
| Y | x |  | k | S(y←x) | S(y→x) | S(y<=>x) |
| Δ4ln(GDPr) | Δ4ln(M1r) | 0.179(\*) | 4 | 16.547\*\* | 7.036 | 26.771\*\* |
|  |  |  | 8 | 17.234\* | 11.005 | 31.426\* |
| Δ4ln(GDPr) | GLR – GSR | 0.076 | 4 | 6.031 | 10.218\* | 16.826(\*) |
|  |  |  | 8 | 11.270 | 13.718(\*) | 25.565(\*) |
| Δ4ln(M1r) | GLR – GSR | 0.383\*\*\* | 4 | 11.967\* | 9.660\* | 36.295\*\*\* |
|  |  |  | 8 | 14.424(\*) | 11.270 | 40.362\*\* |
| ‘(\*)’, ‘\*’, ‘\*\*’, or. ‘\*\*\*’ denote that the null hypothesis that no causal relation exists can be rejected at the 10, 5, 1 or 0.1 percent significance level, respectively. | | | | | | |

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| *Table 3.3: Optimal Lag Length for the Hsiao Procedure* | | | | | | |
|  | Akaike Criterion | | | Schwarz Criterion | | |
| Relation |  |  |  |  |  |  |
| Δ4ln(M1r) → Δ4ln(GDPr) | 4 | 1 | 1 | 1 | 1 | 1 |
| Δ4ln(GDPr) → Δ4ln(M1r) | 5 | 3 | 8 | 4 | 0 | 4 |
| (GLR – GSR) → Δ4ln(GDPr) | 4 | 2 | 1 | 1 | 2 | 1 |
| Δ4ln(GDPr) → (GLR – GSR) | 5 | 5 | 5 | 5 | 0 | 5 |

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| *Table 3.4:* *Models Estimated with the Hsiao Procedure 1/65 – 4/89, 100 Observations* | | | | |
| Criterion | Akaike Criterion | | Schwarz Criterion | |
| Explanatory Variable | Dependent Variable | | | |
| Δ4ln(GDPr,t) | Δ4ln(M1r,t) | Δ4ln(GDPr,t) | Δ4ln(M1r,t) |
| Constant term | 0.146 (0.67) | 1.263\*\*\* (3.42) | 0.136 (0.62) | 1.139\*\*\* (3.94) |
| Δ4ln(GDPr, t-1) | 0.751\*\*\* (13.59) | -0.195 (1.32) | 0.756\*\*\* (13.68) |  |
| Δ4ln(GDPr,t-2) |  | -0.283 (1.65) |  |  |
| Δ4ln(GDPr,t-3) |  | 0.369\* (2.54) |  |  |
| Δ4ln(M1r,t-1) | 0.159\*\*\* (4.62) | 1.027\*\*\* (10.73) | 0.159\*\*\* (4.61) | 0.972\*\*\* (10.12) |
| Δ4ln(M1r,t-2) |  | -0.173 (1.29) |  | -0.135 (0.99) |
| Δ4ln(M1r,t-3) |  | 0.185 (1.36) |  | 0.083 (0.61) |
| Δ4ln(M1r,t-4) |  | -0.478\*\*\* (3.53) |  | -0.265\*\* (2.72) |
| Δ4ln(M1r,t-5) |  | 0.340\* (2.50) |  |  |
| Δ4ln(M1r,t-6) |  | -0.188 (1.36) |  |  |
| Δ4ln(M1r,t-7) |  | 0.192 (1.41) |  |  |
| Δ4ln(M1r,t-8) |  | -0.203\* (2.08) |  |  |
| (û1,û2) | 0.012 | | 0.077 | |
| 2 | 0.694 | 0.750 | 0.694 | 0.726 |
| SE | 1.340 | 1.952 | 1.340 | 2.041 |
| Q(m) | 23.084\* | 11.226\* | 23.344\* | 16.548\* |
| m | 11 | 4 | 11 | 8 |
| The numbers in parentheses are the absolute values of the estimated t statistics. ‘(\*)’, ‘\*’, ‘\*\*’, or ‘\*\*\*’ denote that the corresponding null hypothesis can be rejected at the 10, 5, 1 or 0.1 percent significance level, respectively. m denotes the number of degrees of freedom of the Q statistic. | | | | |

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| *Table 3.5:* *Models Estimated with the Hsiao Procedure 1/65 – 4/89, 100 Observations* | | | | |
| Criterion | Akaike Criterion | | Schwarz Criterion | |
| Explanatory Variable | Dependent Variable | | | |
| Δ4ln(GDPr,t) | (GLR – GSR)t | Δ4ln(GDPr,t) | (GLR – GSR)t |
| Constant term | 0.327 (1.47) | 0.404\*\* (2.80) | 0.320 (1.43) | 0.293\*\* (2.93) |
| Δ4ln(GDPr, t-1) | 0.730\*\*\* (12.22) | -0.034 (0.65) | 0.733\*\*\* (12.27) |  |
| Δ4ln(GDPr,t-2) |  | -0.132\* (2.10) |  |  |
| Δ4ln(GDPr,t-3) |  | 0.021 (0.32) |  |  |
| Δ4ln(GDPr,t-4) |  | 0.154\* (2.58) |  |  |
| Δ4ln(GDPr,t-5) |  | -0.083(\*) (1.72) |  |  |
| (GLR – GSR)t-1 | -0.105 (0.64) | 1.128\*\*\* (11.91) | -0.103 (0.63) | 1.138\*\*\* (12.13) |
| (GLR – GSR)t-2 | 0.441\*\* (2.62) | -0.168 (1.27) | 0.438\* (2.60) | -0.198 (1.42) |
| (GLR – GSR)t-3 |  | -0.347\*\* (2.69) |  | -0.316\* (2.32) |
| (GLR – GSR)t-4 |  | 0.481\*\*\* (3.70) |  | 0.448\*\* (3.25) |
| (GLR – GSR)t-5 |  | -0.274\*\* (2.95) |  | -0.327\*\*\* (3.53) |
| (û1,û2) | 0.053 | | 0.031 | |
| 2 | 0.684 | 0.816 | 0.684 | 0.798 |
| SE | 1.362 | 0.732 | 1.362 | 0.768 |
| Q(m) | 16.513 | 4.824 | 16.648 | 7.118 |
| m | 11 | 7 | 11 | 7 |
| The numbers in parentheses are the absolute values of the estimated t statistics. ‘(\*)’, ‘\*’, ‘\*\*’, or ‘\*\*\*’ denote that the corresponding null hypothesis can be rejected at the 10, 5, 1 or 0.1 percent significance level, respectively. m denotes the number of degrees of freedom of the Q statistic. | | | | |

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| *Table 3.6:* *Test for Granger Causality: Direct Granger Procedure with Three Variables 1/65 – 4/89, 100 Observations* | | | | | | |
| Y | x | z | k | F(y←x) | F(y→x) | F(y–x) |
| Δ4ln(GDPr) | Δ4ln(M1r) | GLR – GSR | 4 | 2.747\* | 3.788\*\* | 0.577 |
|  |  |  | 8 | 2.866\*\* | 2.362\* | 0.127 |
| Δ4ln(GDPr) | GLR – GSR | Δ4ln(M1r) | 4 | 0.260 | 2.426(\*) | 0.247 |
|  |  |  | 8 | 1.430 | 1.817(\*) | 0.229 |
| Δ4ln(M1r) | GLR – GSR | Δ4ln(GDPr) | 4 | 7.615\*\*\* | 0.293 | 7.273\*\*\* |
|  |  |  | 8 | 3.432\*\* | 1.009 | 8.150\*\*\* |
| ‘(\*)’, ‘\*’, ‘\*\*’, or ‘\*\*\*’ denote that the null hypothesis that no causal relation exists can be rejected at the 10, 5, 1 or 0.1 percent significance level, respectively. | | | | | | |

4 Vector Autoregressive Processes



*Figure 4.1: Impulse response functions*



*Figure 4.2: Cumulative impulse response functions*



*Figure 4.3: Impulse response functions*



*Figure 4.4: Cumulative impulse response functions*

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| Table 4.1: Variance Decomposition | | | |
| Forecast horizon |  | x1 | x2 |
| Immediate | x1 | 100.000 | 0.000 |
| x2 | 32.834 | 67.166 |
| 4 periods | x1 | 77.866 | 22.134 |
| x2 | 23.089 | 76.911 |
| 8 periods | x1 | 65.085 | 34.915 |
| x2 | 20.957 | 79.043 |
| 20 periods | x1 | 58.527 | 41.473 |
| x2 | 19.838 | 80.162 |
| Infinity | x1 | 58.020 | 41.980 |
| x2 | 19.748 | 80.252 |

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| *Table 4.2a:* *Variance Decomposition  1/65 – 4/89, 100 Observations* | | | | |
| Forecast horizon |  | Δ4ln(GDPr) | Δ4ln(M1r) | GLR – GSR |
| immediate | Δ4ln(GDPr) | 99.231 | 0.483 | 0.286 |
| Δ4ln(M1r) | 0.000 | 92.202 | 7.798 |
| GLR – GSR | 0.000 | 0.000 | 100.000 |
| 1 year | Δ4ln(GDPr) | 82.899 | 12.479 | 4.622 |
| Δ4ln(M1r) | 8.994 | 41.336 | 49.670 |
| GLR – GSR | 9.223 | 0.487 | 90.289 |
| 2 years | Δ4ln(GDPr) | 51.948 | 15.604 | 32.448 |
| Δ4ln(M1r) | 13.896 | 34.910 | 51.194 |
| GLR – GSR | 16.124 | 8.998 | 74.878 |
| 5 years | Δ4ln(GDPr) | 48.235 | 16.049 | 35.716 |
| Δ4ln(M1r) | 14.738 | 35.244 | 50.018 |
| GLR – GSR | 15.719 | 13.062 | 71.219 |
| infinity | Δ4ln(GDPr) | 48.187 | 16.132 | 35.681 |
| Δ4ln(M1r) | 14.733 | 35.258 | 50.009 |
| GLR – GSR | 15.677 | 13.079 | 71.244 |

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| *Table 4.2b:* *Variance Decomposition 1/65 – 4/89, 100 Observations* | | | | |
| Forecast horizon |  | Δ4ln(GDPr) | Δ4ln(M1r) | GLR – GSR |
| immediate | Δ4ln(GDPr) | 99.231 | 0.667 | 0.102 |
| Δ4ln(M1r) | 0.000 | 100.000 | 0.000 |
| GLR – GSR | 0.000 | 7.798 | 92.292 |
| 1 year | Δ4ln(GDPr) | 82.899 | 15.740 | 1.361 |
| Δ4ln(M1r) | 8.994 | 60.685 | 30.321 |
| GLR – GSR | 9.223 | 7.326 | 83.450 |
| 2 years | Δ4ln(GDPr) | 51.948 | 26.995 | 21.057 |
| Δ4ln(M1r) | 13.896 | 50.669 | 35.435 |
| GLR – GSR | 16.124 | 11.184 | 72.692 |
| 5 years | Δ4ln(GDPr) | 48.235 | 25.978 | 25.787 |
| Δ4ln(M1r) | 14.738 | 50.970 | 34.292 |
| GLR – GSR | 15.719 | 16.065 | 68.216 |
| infinity | Δ4ln(GDPr) | 48.187 | 26.033 | 25.780 |
| Δ4ln(M1r) | 14.733 | 50.999 | 34.269 |
| GLR – GSR | 15.677 | 16.136 | 68.188 |

5 Nonstationary Processes



*Figure 5.1: Linear and quadratic trend, superimposed   
by a pure random process*



*Figure 5.2: Realisations of AR(1) processes α = 1.03 (------), α= 0.97 (———)*



*Figure 5.3: Random walk with (-----) and without (––––) drift*





*Figure 5.4: Scatter diagrams of the first differences against the  
original residuals of nonstationary processes*





*Figure 5.5: Scatter diagrams of the residuals of regressions on a time trend against the original residuals of nonstationary processes*





*Figure 5.6 Actual and estimated values and residuals of the models with linear deterministic and stochastic trends*

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| *Table 5.1:*  *Results of Linear Trend Elimination (100 Observations)* | | | |
|  | Model with a | | |
|  | linear trend | random walk | random walk with drift |
| Constant term | 5.678  (9.79) | 19.673  (16.89) | 18.673  (16.03) |
| linear trend | 0.993  (99.60) | 0.191  (9.55) | 1.191  (59.48) |
|  | 0.990 | 0.477 | 0.973 |
| Durbin-Watson | 2.085 | 0.247 | 0.247 |



*Figure 5.7: Density of the estimated autocorrelation coefficient and the  
t statistic under the null hypothesis of a random walk.*



Figure 5.8: Development of the Swiss, German/European and US  
 Euromarket interest rates. Monthly data,   
January 1983 – December 2002

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| *Table 5.2:* *Results of the Augmented Dickey-Fuller Tests 1/1983 – 12/2002, 240 Observations* | | | | |
| Variable | Levels | | 1. Differences | |
| k | Test Statistic | k | Test Statistic |
| SER | 3 | -1.194 (0.678) | 2 | -7.862 (0.000) |
| GER/eER | 1 | -0.957 (0.768) | 0 | -11.962 (0.000) |
| UER | 1 | -0.995 (0.755) | 0 | -11.220 (0.000) |
| The tests were performed for levels with as well as for first differences without a constant term. The numbers in parentheses are the p values. The number of lags, k, has been determined with the Hannan-Quinn criterion. | | | | |



*Figure 5.9a: Density of the estimated coefficient and of the t statistic for the null hypothesis*

*of an AR(1) process with ρ = 0.95*



*Figure 5.9b: Density of the estimated coefficient and of the t statistic  
 for the null hypothesis of an AR(1) process with ρ = 0.90*

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| *Table 5.3:* *Results of Unit Root and Stationarity Tests for Inflation 1/1969 – 9/1992, 285 Observations* | | | | | | |
|  | m/k | United States | United Kingdom | France | Germany | Italy |
| Phillips- Perron | 6  12 | -8.95\*\*  -10.20\*\* | -9.30\*\*  -10.54\*\* | -5.82\*\*  -6.84\*\* | -10.32\*\*  -11.65\*\* | -6.40\*\*  -7.39\*\* |
| KPSS | 6  12 | 0.81\*\*  0.51\* | 1.02\*\*  0.65\*\* | 1.57\*\*  0.91\*\* | 1.26\*\*  0.80\*\* | 0.94\*\*  0.56\*\* |
| ADF | 3  6  12 | -4.43\*\*  -3.06\*  -1.86 | -4.48\*\*  -2.97\*  -2.27 | -2.71(\*)  -1.71  -1.29 | -4.98\*\*  -3.49\*\*  -1.75 | -3.31\*  -2.24  -2.39 |
| ‚(\*)‘, ,\*‘ or ,\*\*‘ denote that the corresponding null hypothesis can be rejected at the 10, 5, or 1 percent significance level, respectively.  Source: U. Hassler and J. Wolters (1995, *Tables 3* and *4*, p. 39). | | | | | | |



*Figure 5.10a: German Inflation Rate: Actual values (––––), permanent component according to S. Beveridge and CH.R. Nelson (-------), permanent component according to R.J. Hodrick and E.C. Prescott (– ‑ – ‑ –)*



*Figure 5.10b: German Inflation Rate: cyclical component according to S. Beveridge and CH.R. Nelson (--------), cyclical component according to R.J. Hodrick and E.C. Prescott (––––)*

*Figure 5.11a: Swiss real money balances M2, 1981 – 2008: Actual values (––––)*

*and permanent component (--------) due to the Hodrick-Prescott filter*

*Figure 5.11b: Swiss real money balances M2, 1981 – 2006: Actual values  
(––––) and permanent component (--------) due to the Hodrick-Prescott filter*

6 Cointegration



*Figure 6.1: Densities of the estimated t value, R2, and   
the Durbin-Watson statistic*

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| *Table 6.1:* *Critical Values of the Dickey-Fuller Test on Cointegration in the Static Model* | | | | |
| α | k | | | |
| 1 | 2 | 3 | 4 |
|  | Model with constant term | | | |
| 0.10 | -2.57 | -3.05 | -3.45 | -3.81 |
| 0.05 | -2.86 | -3.34 | -3.74 | -4.10 |
| 0.01 | -3.43 | -3.90 | -4.30 | -4.65 |
|  | Model with constant term and time trend | | | |
| 0.10 | -3.13 | -3.50 | -3.83 | -4.15 |
| 0.05 | -3.41 | -3.78 | -4.12 | -4.43 |
| 0.01 | -3.96 | -4.33 | -4.67 | -4.97 |
| The values for k = 1 are the critical values of the Dickey-Fuller unit root test.  Source: J.G. MacKinnon (1991, *Table 1*, p. 275). | | | | |



a) Logarithm of the per capita real quantity of money M1



b) Logarithm of the per capita real GNP



c) Long-run interest rate

*Figure 6.2: Data for the Federal Republic of Germany, 1961 − 1989*

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| *Table 6.2:*  *Critical Values of the Cointegration Test in the Error Correction Model* | | | |
| α | k | | |
| 2 | 3 | 4 |
|  | Model with constant term | | |
| 0.10 | -2.89 | -3.19 | -3.42 |
| 0.05 | -3.19 | -3.48 | -3.74 |
| 0.01 | -3.78 | -4.06 | -4.46 |
|  | Model with constant term and time trend | | |
| 0.10 | -3.39 | -3.62 | -3.82 |
| 0.05 | -3.69 | -3.91 | -4.12 |
| 0.01 | -4.27 | -4.51 | -4.72 |
| Source: A. Banerjee, J.J. Dolado and R. Mestre (1998, *Table 1*, pp. 276f.) | | | |



*Figure 6.3: German three month money market rate in Frankfurt*

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| *Table 6.3:*  *Results of the Johansen Cointegration Test* | | | | |
| Model | Hypotheses | Eigenvalues | Trace Test | λmax Test |
| z1, z3 |  |  |  |  |
| z1, z6 |  |  |  |  |
| The numbers in parentheses are the p values of the corresponding statistics. | | | | |

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| *Table 6.4:*  *Results of the Johansen Cointegration Test* | | | | |
| Model | Hypotheses | Eigenvalues | Trace Test | λmax Test |
| z1, z3, z6 VECM(0) |  |  |  |  |
| z1, z3, z6 VECM(1) |  |  |  |  |
| The numbers in parentheses are the p values of the corresponding statistics. | | | | |

7 Nonstationary Panel Data

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*Figure 7.1: 10 year government bond yields, January 1990 – December 2006*

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| *Table 7.1:**p values of the Augmented Dickey-Fuller Tests for 10 year government bonds* | | | | | |
|  | p |  | p |  | p |
| Australia  Canada  Denmark  Germany | 0.1503  0.3168  0.3392  0.4502 | Japan  New Zealand  Norway  Sweden | 0.3254  0.0600  0.2677  0.2060 | Switzerland  United Kingdom  United States | 0.4564  0.3910  0.2298 |



*Figure 7.2: Cross-sectional average of the U.S. spreads*

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| *Table 7.2:**CADF Test statistics for spreads against the U.S.* | | | | | |
|  | tρ | ki |  | tρ | ki |
| Australia  Canada  Denmark  Germany  Japan | -2.96  -3.69  -3.92  -5.05  -2.80 | 0  0  0  0  2 | New Zealand  Norway  Sweden  Switzerland  United Kingdom | -2.55  -3.13  -1.70  -3.20  -2.90 | 0  2  1  0  2 |

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| *Table 7.3:* *Ordered p values for Augmented Dickey-Fuller tests for the spreads with α = 0.1* | | | | | |
|  | p(j) | j⋅α/10 |  | p(j) | j⋅α/10 |
| New Zealand  Switzerland  Australia  United Kingdom  Germany | 0.0298  0.0406  0.1044  0.1371  0.1385 | 0.01  0.02  0.03  0.04  0.05 | Norway  Denmark  Sweden  Japan  Canada | 0.1545  0.2070  0.2367  0.3152  0.4717 | 0.06  0.07  0.08  0.09  0.10 |

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| --- | --- | --- | --- | --- | --- |
| *Table 7.4:* *Ordered p values for tests for no cointegration* | | | | | |
|  |  | p(j) |  |  | p(j) |
| Denmark  Sweden  United Kingdom  New Zealand  Germany | 1.45  1.95  1.56  1.16  1.13 | 0.0748  0.0841  0.0882  0.1120  0.1200 | Switzerland  Australia  Canada  Norway  Japan | 0.96  1.56  1.35  1.33  1.26 | 0.1474  0.1705  0.2394  0.3324  0.4114 |

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| --- | --- | --- | --- | --- | --- | --- |
| *Table 7.5:* *Estimates of the error correction adjustment coefficient* | | | | | | |
|  | γi | |  | γi | | |
| OLS | SUR | OLS | SUR | |
| Australia  Canada  Denmark  Germany  Japan | -0.045 (-2.77)  -0.036 (-1.56)  -0.065 (-3.47)  -0.063 (-2.06)  -0.022 (-1.13) | -0.067 (-5.12)  -0.066 (-3.68)  -0.079 (-6.05)  -0.083 (-5.67)  -0.037 (-2.54) | New Zealand  Norway  Sweden  Switzerland  United Kingdom | -0.062 (-2.75)  -0.050 (-2.97)  -0.032 (-3.03)  -0.060 (-2.03)  -0.044 (-2.69) | | -0.064 (-3.63)  -0.060 (-4.64)  -0.043 (-4.49)  -0.075 (-4.27)  -0.057 (-4.34) |
| The numbers in parentheses are the t statistics of the estimated parameters. | | | | | | |

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| *Table 7.6:* *Estimates of the short-run US influence* | | | | | |
|  |  |  |  |  |  |
| Australia  Canada  Denmark  Germany  Japan | 0.224 (2.39)  0.104 (1.19)  0.070 (0.98)  0.127 (2.23)  0.103 (1.82) | 0.269 (2.83)  0.151 (1.73)  0.136 (1.88)  0.176 (3.08)  0.123 (2.18) | New Zealand  Norway  Sweden  Switzerland  United Kingdom | 0.075 (0.91)  0.031 (0.42)  0.010 (0.12)  0.047 (0.93)  0.049 (0.61) | 0.114 (1.38)  0.092 (1.25)  0.049 (0.57)  0.100 (1.96)  0.087 (1.07) |
| The numbers in parentheses are the t statistics of the estimated parameters. | | | | | |

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| *Table 7.7:* *SUR error correction estimates* | | | |
|  |  |  |  |
| Australia  Canada  Denmark  Germany  Japan | 0.828  0.957  1.338  1.096  0.590 | New Zealand  Norway  Sweden  Switzerland  United Kingdom | 0.588  1.312  1.638  0.938  1.246 |

8 Autoregressive Conditional Heteroscedasticity



a) German Stock Market Index: Data



b) German Stock Market Index: Continuous returns



c) German Stock Market Index: Histogram of the continuous returns

*Figure 8.1: German Stock Market Index, 2 January 1996 until 19 May 1999, 842 observations*

|  |
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| d) Estimated autocorrelations of the residuals    e) Estimated autocorrelations of the squared residuals |

*Figure 8.1: German Stock Market Index, 2 January 1996 until 19 May 1999, 842 observations (continued)*



*Figure 8.2: Density functions of a normalised t distribution with 5 degrees of freedom, variance one and a standard normal distribution*