# TIME SERIES ECONOMETRICS II

# UNIT ROOTS AND COINTEGRATION

This course is about the econometric analysis of nonstationary data. While it continues Time Series Econometrics I, all the background material from the previous course that is needed will be made available in some Review Lecture Notes at the beginning of this course. The subject is nonstationary time series and its applications in econometrics. We will cover asymptotic methods for nonstationary processes including functional limit theory and stochastic integration, unit root tests, tests of stationarity, spurious regression, cointegrated systems, cointegration tests, reduced rank regression and estimation of models with cointegration. We will also look at long memory models, semiparametric estimation of fractional integration, and introduce some new work on spatial density analysis for nonstationary data, nonlinear integration and panel cointegration. We will not be able to cover all the topics given in the readings below in the same depth but we will try to touch on each of these topics at some point in the course. Credit is obtained from a take home examination and/or an empirical application.

A set of my past lecture notes and some printed lectures I gave at the IMF in 1998 and 2003 will be available. These notes will cover many of the topics that we will talk about in lectures. With these, the course should be fairly self-contained.

**0. General References<sup>1</sup>:** The reading guide of Time Series Econometrics I has a more complete list of references in time series. The items below are largely supplementary to that general list. An annotated bibliography on unit root nonstationarity and unit root tests is provided in Phillips (1997), and Phillips and Xiao (1998).

- Banerjee, A., J. Dolado, J.W. Galbraith and D.F. Hendry (1993) *Cointegration, Error-Correction* and the Econometric Analysis of Non-Stationary Data. Oxford: Oxford University Press.
- Clements M. P. and D. F. Hendry (1999) *Forecasting Nonstationary Economic Time Series*. Cambridge: MIT Press.
- \* Davidson, J. (1994) *Stochastic Limit Theory: An Introduction for Econometricians*. Oxford University Press.
- \*\* Dhrymes, P. (1998) *Time Series, Unit Roots and Cointegration.* San Diego: Academic Press.
  - Engle, R. F. and H. White (1999). *Cointegration, Causality and Forecasting*. Oxford: Oxford University Press.
  - Franses, P.H. (1996) *Periodicity and Stochastic Trends in Economic Time Series*. Oxford: Oxford University Press.
  - Fuller, W.A. (1976/1996) Introduction to Statistical Time Series. New York: Wiley.

<sup>&</sup>lt;sup>1</sup> Asterisked references are more important to the course. Double-asterisked references are principal sources.

- Gallant, A.R. and H. White (1988) A Unified Theory of Estimation and Inference for NonLinear Dynamic Models. Oxford: Basil Blackwell.
- Ghysels, E. and D. R. Osborn (2001). *The Econometric Analysis of Seasonal Time Series*. Cambridge: Cambridge University Press.
- Gourieroux C. and J. Jasiak (2001) Financial Econometrics. Princeton: Princeton University Press.
- Hall, P. and C.C. Heyde (1980) *Martingale Limit Theory and its Applications*. New York: Academic Press.

Hamilton, J.D. (1994) Time Series Analysis. Princeton: Princeton University Press.

- Hansen, P. and S. Johansen (1998). Workbook on Cointegration. Oxford: Oxford University Press.
- \* Hatanaka, M. (1996) *Time-Series Based Econometrics*. Oxford: Oxford University Press.
  - Hatanaka M. and H. Yamada. (2003). Co-trending: A Statistical Systems Analysis of Economic Trends. Springer.
- \* Johansen, S. (1995) Likelihood Based Inference in Cointegrated Vector Autoregressive Models. Oxford: Oxford University Press..
  - Lutkepohl, H. (1993) Introduction to Multiple Time Series Analysis, 2nd ed. New York: Springer Verlag.
  - McAleer, M. and L. Oxley (1999) Practical Issues in Cointegration Analysis, Oxford: Blackwell.
  - Maddala, G. S. and I-M Kim (1998) *Unit Roots, Cointegration and Structural Change,* Cambridge: Cambridge University Press.
- \*\* Ouliaris, S. and P. C. B. Phillips (1993). COINT 2.0: GAUSS Procedures for Cointegrating Regression. Aptech Systems, Washington.
- \* Phillips, P.C.B. (1988) "Multiple Regression with Integrated Time Series," *Contemporary Mathematics*, 80:79–105.
  - Phillips, P.C.B. (1992) "Unit Roots." In P. Newman, M. Milgate and J. Eatwell, eds., *The New Palgrave Dictionary of Money and Finance*, 726–730.
  - Phillips, P.C.B. (1995) "Unit Roots and Cointegration: Recent Books and Themes for the Future," *Journal of Applied Econometrics.*
- \*\* Phillips, P.C.B. (1995) "Lecture Notes on Unit Roots, Cointegration and Nonstationarity", Yale University.
  - Phillips, P.C.B. (1997) "Unit Roots Tests," *Encyclopedia of Statistical Sciences, Vol. 12.* New York: John Wiley.
- \*\* Phillips, P.C.B. (1998) "Econometric Analysis of Nonstationary Data", IMF Lectures.

- \*\* Phillips, P.C.B. and Z. Xiao (1998) "A Primer on Unit Root Testing," *Journal of Economic Surveys*, Vol. 12, No. 5, pp. 423-470.
  - Rao, B.B. (1994) Cointegration for the Applied Economist. St. Martin's Press.

Reinsel, G. (1993) Elements of Multivariate Time Series Analysis. New York: Springer-Verlag.

- \* Stock, J.H. (1995) "Unit Roots, Structural Breaks and Trends." In R.F. Engle and D. McFadden, eds., *Handbook of Econometrics*, Vol. 4. Amsterdam: North Holland.
- \* Tanaka, K. (1996) "Time Series Analysis: Nonstationary and Noninvertible Distribution Theory" New York: Wiley.
  - Taniguchi, M. and Y. Kakizawa (2000). Asymptotic Theory of Statistical Inference for Time Series. New York: Springer Verlag.
- \* Watson, M. (1995) "Vector Autoregressions and Cointegration." In R.F. Engle and D. McFadden, eds., *Handbook of Econometrics*, Vol. 4. Amsterdam: North Holland.
  - White, H. (1994) *Estimation, Inference and Specification Analysis.* Cambridge: Cambridge University Press.

# 1. Review: Stationary Time Series, Prediction, Ergodicity, Linear Processes, Limit Theory and Martingales

Beveridge, S. and R. Nelson (1981) "A New Approach to Decomposition of Time Series in Permanent and Transitory Components with Particular Attention to Measurement of the `Business Cycle'," *Journal of Monetary Economics*, 7:151–174.

Hall and Heyde (1980) op.cit.

- Hannan, E. J. (1963) "Regression for Time Series" in M. Rosenblatt (Ed.) *Time Series Analysis*, New York: Wiley.
- Hannan, E.J. (1970) Multiple Time Series. New York: Wiley.
- Phillips, P.C.B. (1989) *Lecture Notes on Stationary and Nonstationary Time Series*. Vienna: Institute of Advanced Studies.
- Phillips, P.C.B. (1988) "Reflections on Econometric Methodology," *Economic Record*, 64:334–359.
- Phillips, P.C.B. (1995) "Review Lecture: Time Series Econometrics I", Yale University.
- Phillips, P.C.B. and V. Solo (1992) "Asymptotics for Linear Processes" Annals of Statistics, 20:971–1001.

White, H. (1984/2001) Asymptotic Theory for Econometricians. New York: Wiley.

#### 2. Nonstationarity and Trends: Ideas and Challenges, Models and Scope of Interest

Phillips, P.C.B. (1995) "Unit Roots and Cointegration: Recent Books and Themes for the Future," *Journal of Applied Econometrics*.

Phillips, P.C.B. (2003) "Challenges of Trending Time Series Econometrics" mimeographed.

# 3. Functional Central Limit Theory and Applications to Unit Root Asymptotics

Billingsley, P. (1968) Weak Convergence of Probability Measures. New York: Wiley.

Chan, N.H. and C.Z Wei (1987) "Asymptotic Inference for Nearly Nonstationary AR(1) Processes," *Annals of Statistics*, 15:1050–1063.

Chan, N. H. and C. Z. Wei (1988). "Limiting distributions of least squares estimates of unstable autoregressive processes," *Annals of Statistics*, 16, 367–401.

- Jeganathan, P. (1991) "On the Asymptotic Behavior of Least Squares Estimators in AR Time Series with Roots near the Unit Circle," *Econometric Theory*, 7:269–306.
- Jeganathan, P. (1995) "Some Aspects of Asymptotic Theory with Applications to Time Series Models," *Econometric Theory*, 11, 818-887.
- Phillips, P.C.B. (1987) "Towards a Unified Asymptotic Theory for Autoregression," *Biometrika*, 74:535–547.
- Phillips, P.C.B. (1988) op cit.
- Phillips, P.C.B. and S.N. Durlauf (1986) "Multiple Time Series Regression with Integrated Processes," *Review of Economic Studies*, 53:473–496.

# 4. Stochastic Integration, Ito Calculus and Weak Convergence to Stochastic Integrals

- Chung K.L. and R.J. Williams (1990). "An Introduction to Stochastic Integratrion". Boston: Birkhauser.
- Ikeda, N. and S. Watanabe (1989). *Stochastic Differential Equations and Diffusion Processes* (Second Edition). Amsterdam: North Holland.
- Jacod, J. and A. N. Shiryaev (1987). *Limit Theorems for Stochastic Processes*. New York: Springer Verlag.
- Karatzas, I. and S.E. Shreve (1991). *Brownian Motion and Stochastic Calculus*. New York: Springer Verlag.
- Kopp P. E. (1984). Martingales and Stochastic Integrals. Cambridge: Cambridge University Press.
- Phillips, P. C. B. (1988). "Weak convergence of sample covariance matrices to stochastic integrals via martingale approximations," *Econometric Theory*, 4, 528–533.

- Protter, P. (1990). *Stochastic Integration and Differential Equations: A New Approach*. New York: Springer Verlag.
- Revuz D. And M. Yor (1998). *Continuous Martingales and Brownian Motion (3'rd Edition)*. New York: Springer Verlag.

#### 5. Unit Root Tests and Applications

- Banerjee, A., Lumsdaine, R. and Stock, J.H. (1992) "Recursive and Sequential Tests of the Unit Root and Trend Break Hypotheses: Theory and International Evidence," *Journal of Business and Economic Statistics*, 10:271–288.
- Bhargava, A. (1986) "On the Theory of Testing for Unit Roots in Observed Time Series," *Review of Economic Studies*, 53(174):369–384.
- Bierens, H.J. and S. Guo (1993) "Testing Stationarity and Trend Stationarity Against the Unit Root Hypothesis," *Econometric Reviews*, 12:1–32.
- Blough, S.R. (1992) "The Relationship Between Power and Level for Generic Unit Root Tests in Finite Samples," *Journal of Applied Econometrics*, 7:295–308.
- Campbell, J.Y. and P. Perron (1991) "Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Roots," *NBER Macroeconomics Annual*, 141–200.
- Cochrane, J.H. (1988) "How Big is the Random Walk in GNP?" *Journal of Political Economy*, 96:893–920.
- Cochrane, J.H. (1991a) "A Critique of the Application of Unit Root Tests," *Journal of Economic Dynamics and Control*, 15:275–284.
- Cochrane, J.H. (1991b) "Comment on Campbell and Perron" *NBER Macroeconomics Annual*, 5:201–210.
- DeJong, D.N., J.C. Nankervis, N.E. Savin and C.H. Whiteman (1992a) "Integration versus Trend-Stationarity in Macroeconomic Time Series," *Econometrica*, 60:423–434.
- DeJong, D.N., J.C. Nankervis, N.E. Savin and C.H. Whiteman (1992b) "The Power Problems of Unit Root Tests for Time Series with Autoregressive Errors," *Journal of Econometrics*, 53:323–343.
- Dickey, D.A. and W.A. Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, 74:427–431.
- Dickey, D.A. and W.A. Fuller (1981) "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica*, 49:1057–1052.
- Dickey, D.A., D.P. Hasza, and W.A. Fuller (1984) "Testing for Unit Roots in Seasonal Time Series," *Journal of the Americal Statistical Association*, 79:355–367.

- Dickey, D.A. and S.G. Pantula (1987) "Determining the Order of Differencing in Autoregressive Processes," *Journal of Business and Economic Statistics*, 5:455–462.
- Elliott, G., T.J. Rothenberg and J.H. Stock (1997) "Efficient Tests for an Autoregressive Unit Root," *Econometrica*, 1997.
- Evans, G.B.A. and N.E. Savin (1984) "Testing for Unit Roots: 1," Econometrica, 49:753-779.
- Evans, G.B.A. and N.E. Savin (1984) "Testing for Unit Roots: 2," Econometrica, 52:1241-1269.

Fuller (1976) op. cit.

- Ghysels, E. and P. Perron (1993) "The Effect of Seasonal Adjustment Filters on Tests for a Unit Root," *Journal of Econometrics*, 55:57–98.
- Hall, A. (1989) "Testing for a Unit Root in the Presence of Moving Average Errors," *Biometrika*, 76:49–56.
- Hall, A. (1992) "Testing for a Unit Root in Time Series Using Instrumental Variable Estimation with Pretest Data-Based Model Selection," *Journal of Econometrics*, 54:223–250.
- Hall, R.E. (1978) "Stochastic Implications of the Life Cycle Permanent Income Hypothesis: Theory and Evidence," *Journal of Political Economy*, 86(6):971–987.
- Hylleberg, S., R.F. Engle, C.W.J. Granger and S. Yoo (1990) "Seasonal Integration and Cointegration," *Journal of Econometrics*, 44:215–238.
- Nelson, C.R. and C.I. Plosser (1982) "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications," *Journal of Monetary Economics*, 10:139–162.
- Ouliaris, S., J. Y. Park and P. C. B. Phillips (1989), "Testing for a unit root in the presence of a maintained trend," Chapter 1 in Advances in Econometrics and Modelling, B. Raj, editor, Norwell, MA: Kluwer Academic Publishers.
- Park, J. (1990) "Testing for Unit Roots and Cointegration by Variable Addition." In G.F. Rhodes and T.B. Fomby, eds., Advances in Econometrics: Cointegration, Spurious Regressions and Unit Roots. Greenwich, CT: JAI Press.
- Perron, P. (1988) "Trends and Random Walks in Macroeconomic Time Series: Further Evidence from a New Approach," *Journal of Economic Dynamics and Control*, 12:297–332.
- Perron, P. (1989) "The Great Crash, the Oil Price Shock and the Unit Root Hypothesis," *Econometrica*, 57:1361–1401.
- Perron, P. and P.C.B. Phillips (1987) "Does GNP Have a Unit Root? A Reevaluation," *Economic Letters*, 23:139–145.
- Perron, P. and T.S. Vogelsang (1992) "Nonstationarity and Level Shifts with an Application to Purchasing Power Parity," *Journal of Business and Economic Statistics*, 10:301–320.

Phillips, P. C. B. (1987). "Time series regression with a unit root," *Econometrica*, 55, 277–301.

- Phillips, P.C.B. and P. Perron (1987) "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75:335–346.
- Quah, D. (1992) "The Relative Importance of Permanent and Transitory Components: Identification and Some Theoretical Bounds," *Econometrica*, 60(1):107–118.
- Robinson, P.M. (1994) "Efficient Tests of Nonstationary Hypotheses," *Journal of the American Statistical Association*.
- Said, S.E. and D.A. Dickey (1984) "Testing for Unit Roots in Autoregressive–Moving Average Models of Unknown Order," *Biometrika*, 71:599–608.
- Said, S.E. and D.A. Dickey (1985) "Hypothesis Testing in ARIMA (*p*,1,*q*) Models" *Journal of the American Statistical Association*, 80:369–374.
- Schmidt, P. and P.C.B. Phillips (1992) "LM Tests for a Unit Root in the Presence of Deterministic Trends," *Oxford Bulletin of Economics and Statistics*, 54:257–287.
- Schwert, G.W. (1987) "Effects of Model Misspecification on Tests for Unit Roots in Macroeconomic Data," *Journal of Monetary Economics*, 20:73–103.
- Schwert, G.W. (1989) "Tests for Unit Roots: A Monte Carlo Investigation," Journal of Business and Economic Statistics, 7:147–159.
- Solo, V. (1984) "The Order of Differencing in ARIMA Models," *Journal of the American Statistical Association*, 79:916–921.
- Sowell, F.B. (1990) "Fractional Unit Root Distribution," Econometrica, 58:495–506.
- Sowell, F.B. (1992) "Maximum Likelihood Estimation of Stationary Univariate Fractionally Integrated Time Series Models," *Journal of Econometrics*, 53:165–188.
- Stock, J.H. (1991) "Confidence Intervals for the Largest Autoregressive Root in U.S. Economic Time Series," *Journal of Monetary Economics*, 28(3):435–460.
- Stock, J.H. and M.W. Watson (1988) "Variable Trends in Economic Time Series," *Journal of Economic Perspectives*, 2(3):147–174.
- Tanaka, K. (1990) "The Fredholm Approach to Asymptotic Inference in Nonstationary and Noninvertible Time Series Models," *Econometric Theory*, 6(4):411–432.
- Watson, M.W. (1986) "Univariate Detrending Methods with Stochastic Trends," Journal of Monetary Economics, 18:49–75.
- West, K.D. (1987) "A Note on the Power of Least Squares Tests for a Unit Root," *Economics Letters*, 24:1397–1418.
- West, K.D. (1988a) "Asymptotic Normality when Regressors Have a Unit Root," *Econometrica*, 56:1397–1418.

- West, K.D. (1988b) "On the Interpretation of Near Random Walk Behavior in GNP," *American Economic Review*, 78:202–208.
- Zivot, E. and Andrews, D.W.K. (1992) "Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root Hypothesis," *Journal of Business and Economic Statistics*, 10:251–270.

### 6. Trends and Efficient Trend Elimination

- Canjels, N. and M. Watson (1997). ``Estimating deterministic trends in the presence of serially correlated errors,'' *Review of Economics and Statistics*.
- Grenander, U. and M. Rosenblatt (1957). *Statistical Analysis of Stationary Time Series*. New York: Wiley.
- Phillips, P. C. B. And C. C. Lee (1996). "Efficiency gains from quasi-differencing under nonstationarity." In P. M. Robinson and M. Rosenblatt (eds.), *Essays in Memory of E. J. Hannan*, Springer Verlag: New York.
- Phillips, P. C. B. and J. Y. Park (1988). "Asymptotic equivalence of ordinary least squares and generalized least squares in regressions with integrated regressors," *Journal of the American Economic Association*, 83:401, 111–115.
- Xiao, Z. and P. C. B. Phillips (1998) "Higher Order Approximations for Frequency Domain Time Series Regression", *Journal of Econometrics*, 1998 (forthcoming).
- Xiao, Z. and P. C. B. Phillips (1997) "Efficient Detrending in Cointegrating Regression", Yale University, mimeographed,

#### 7. Testing Stationarity

- Kwiatkowski, D., P.C.B. Phillips, P. Schmidt and Y. Shin (1992) "Testing the Null Hypothesis of Stationarity Against the Alternatives of a Unit Root: How Sure Are We That Economic Time Series Have a Unit Root?," *Journal of Econometrics*, 54:159–178.
- Nabeya, S. and K. Tanaka (1988) "Asymptotic Theory of a Test for the Constancy of Regression Coefficients Against the Random Walk Alternative," *Annals of Statistics*, 16:218–235.
- Nyblom, J. (1986) "Testing for Deterministic Linear Trend in Time Series," *Journal of the American Statistical Association*, 81:545–549.
- Nyblom, J. (1989) "Testing for Constancy of Parameters over Time," *Journal of the American Statistical Association*, 84:223–230.
- Saikkonen, P. and R. Luukkonen (1993a) "Testing for Moving Average Unit Root in Autoregressive Integrated Moving Average Models," *Journal of American Statistical Association*, 88:596–601.
- Saikkonen, P. and R. Luukkonen (1993b) "Point Optimal Tests for Testing the Order of Differencing in ARIMA Models," *Econometric Theory*, 9(3):343–362.

Tanaka, K. (1990b) "Testing for a Moving Average Unit Root," *Econometric Theory*, 6(4):433–444.

#### 8. Spurious Regression

- Durlauf, S.N. and P.C.B. Phillips (1988) "Trends versus Random Walks in Time Series Analysis," *Econometrica*, 56, 1333–1354.
- Entorf, H. (1997). "Random walks with drifts: nonsense regression and spurious fixed effect estimation" *Journal of Econometrics*, 80, 287-296.
- Granger, C.W.J. and P. Newbold (1974) "Spurious Regressions in Econometrics," *Journal of Econometrics*, 2:111–120.
- Nelson, C.R. and H. Kang (1981) "Spurious Periodity in Inappropriately Detrended Time Series," *Econometrica*, 49:741–751.
- Numes, L. C., C-M. Kuan and P. Newbold (1995) "Spurious Break" *Econometric Theory*, 11, 736-749.
- Phillips, P.C.B. (1986) "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics*, 33:311–340.
- Phillips, P.C.B. (1989) "Partially Identified Econometric Models," *Econometric Theory*, 5:181–240.
- Phillips, P.C.B. (1996) "Spurious Regression Unmasked," *Cowles Foundation Discussion Paper*, No. 1135.
- Phillips, P.C.B. (1998) "New Tools for Understanding Spurious Regressions" *Econometrica*, 66, pp. 1299-1326.
- Phillips, P.C.B. (2001) "New Unit Root Asymptotics in the Presence of Deterministic Trends" *Journal of Econometrics* (forthcoming).
- Phillips, P.C.B. (2001) "Bootstrapping Spurious Regression", mimeographed, Cowles Foundation, Yale University.
- Phillips, P.C.B. and H. Moon (1999) "Linear Regression Limit Theory for Nonstationary Panel Data Panel," *Econometrica*, 67, pp.1057-1111

#### 9. General Theory of Regression with Integrated Processes

- Park, J.Y. and P.C.B.Phillips (1988) "Statistical Inference in Regressions with Integrated Processes: Part I," *Econometric Theory*, 4:468–498.
- Park, J.Y and P.C.B. Phillips (1989) "Statistical Inference in Regressions with Integrated Processes: Part II," *Econometric Theory*, 5:95–132.

Phillips, P.C.B. (1988) op.cit.

Sims, C.A., J.H. Stock and M.W. Watson (1990) "Inference in Linear Time Series with Some Unit Roots," *Econometrica*, 58:113–144.

#### 10. Cointegration and Tests for Cointegration

- Ahn, S.K. and G.C. Reinsel (1988) "Nested Reduced Rank Autoregressive Models for Multiple Time Series," *Journal of American Statistical Association*, 83:849–856.
- Ahn, S.K. and G.C. Reinsel (1990) "Estimation for Partially Nonstationary Multivariate Autoregressive Models," *Journal of the American Statistical Association*, 85:813–823.
- Campbell, J.Y. and R.J. Shiller (1987) "Cointegration and Tests of Present Value Models," *Journal of Political Economy*, 95:1062–1088. Reprinted in *Long-Run Economic Relations: Readings in Cointegration*, edited by R.F. Engle and C.W.J. Granger, Oxford University Press, New York, 1991.
- Engle, R.F. and C.W.J. Granger (1987) "Cointegration and Error Correction: Representation, Estimation and Testing," *Econometrica*, 55:251–276.
- Harris, D. and B. Inder (1994) "A test of the null hypothesis of cointegration." in C. Hargreaves (ed.) *Nonstationary times series analysis and cointegration.* Oxford: Oxford University Press.
- Johansen, S. (1988a) "Statistical Analysis and Cointegrating Vectors," *Journal of Economic Dynamics and Control*, 12:231–254.
- Johansen, S. (1988b) "The Mathematical Structure of Error Correction Models." In N.U. Prabhu, ed., *Contemporary Mathematics, Structural Inference from Stochastic Processes*, Vol. 80. Providence, RI: American Mathematical Society.
- Johansen, S. (1991) "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models," *Econometrica*, 59:1551–1580.
- Johansen, S. (1992a) "Determination of cointegration Rank in the Presence of a Linear Trend," *Oxford Bulletin of Economics and Statistics*, 54:383–397.
- Johansen, S. (1992b) "A Representation of Vector Autoregressive Processes Integrated of Order 2," *Econometric Theory*, 8(2):188–202.
- Johansen, S. and K. Juselius (1990) "Maximum Likelihood Estimation and Inference on Cointegration With Applications to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, 52(2):169–210.
- Johansen, S. and K. Juselius (1992) "Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the PPP and UIP of UK," *Journal of Econometrics*, 53:211–244.

Phillips, P.C.B. (1991a) "Optimal Inference in Cointegrated Systems," Econometrica, 59:283-306.

- Phillips, P.C.B. (1991b) "Error Correction and Long Run Equilibria in Continuous Time," *Econometrica*, 59:967–980.
- Phillips, P.C.B. (1991c) "Spectral Regression for Cointegrated Time Series" in W. Barnett (ed.), *Nonparametric and Semiparametric Methods in Economics and Statistics*, Cambridge: Cambridge University Press.
- Phillips, P. C. B. (1994). "Some exact distribution theory for maximum likelihood estimators of cointegration coefficients in error correction models," *Econometrica*, 62:1, 73–94.
- Phillips, P.C.B. and M. Loretan (1991) "Estimating Long Run Economic Equilibrium," *Review of Economic Studies*, 58:407–436.
- Phillips, P. C. B. and S. Ouliaris (1988). "Testing for cointegration using principal components methods," *Journal of Economic Dynamics and Control*, 12, 205–230.
- Phillips, P.C.B. and S. Ouliaris (1990) "Asymptotic Properties of Residual Based Tests for Cointegration," *Econometrica*, 58:165–193.
- Stock, J.H. (1987) "Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors," *Econometrica*, 55:1035–1056.
- Stock, J.H. and M.W. Watson (1988) "Testing for Common Trends," *Journal of the American Statistical Association*, 83(404):1097–1107.

Econometric Reviews (1994) [special issue].

Journal of Economic Dynamics and Control, Vol. 12 (1988) [special issue].

Oxford Bulletin of Economics & Statistics, Vol. 48 (1986) [special issue].

Oxford Bulletin of Economics & Statistics, Vol. 54 (1992) [special issue].

#### 11. Causality Tests in Cointegrated Systems

- Sims, C.A., J. Stock and M.W. Watson (1990) "Inference in Linear Time Series Models with Unit Roots," *Econometrica*, 58:113–144.
- Toda, H.Y. and P.C.B. Phillips (1993) "Vector Autoregression and Causality," *Econometrica*, 61:1367–1394.
- Toda, H.Y. and P.C.B. Phillips (1994a) "The Spurious Effect of Unit Roots on Exogeneity Tests in Vector Autoregressions: An Analytical Study," *Journal of Econometrics*, 59:229–255.
- Toda, H.Y. and P.C.B. Phillips (1994b) "Vector Autoregression and Causality: A Theoretical Overview and Simulation Study," *Econometric Reviews*, 13:259–285.

#### 12. Regression Estimation of Cointegrated Systems

- Chang Y. and P.C.B. Phillips (1995), " Time series regression with mixtures of integrated processes" *Econometric Theory*, Vol. 11, no. 5.
- Kitamura, Y. and P.C.B. Phillips (1995) "Fully Modified IV, GIVE and GMM Estimation with Possibly Nonstationary Regressors and Instruments," Cowles Foundation Discussion Paper No. 1082.
- Kitamura, Y. and P.C.B. Phillips (1995) "Efficient IV Estimation in Nonstationary Regression: An Overview and Simulation Study," *Econometric Theory*, Vol. 11, no. 5.
- Park, J.Y. (1992) "Canonical Cointegrating Regression," Econometrica, 60:119–143.
- Phillips, P.C.B. (1995) "Fully Modified Least Squares and Vector Autoregression," *Econometrica*, Vol. 63, No. 5, pp. 1023-1078.
- Phillips, P.C.B. and B.E. Hansen (1990) "Statistical Inference in Instumental Variables Regression with I(1) Processes," *Review of Economic Studies*, 57:99–125.
- Saikkonen, P. (1991) "Asymptotically Efficient Estimation of Cointegrating Regressions," *Econometric Theory*, 7(1):1–21.
- Saikkonen, P. (1992) "Estimation and Testing of Cointegrated Systems by an Autoregressive Approximation," *Econometric Theory*, 8(1):1–27.
- Stock, J.H. and M.W. Watson (1993) "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica*, 61:783–820.

# 13. Strong Dependence and Long Memory

- Akonom, J. and C. Gourieroux (1987). "A Functional Limit Theorem for Fractional Processes." Technical Report, CEPREMAP, Paris.
- Baillie, R. T. (1996). "Long memory processes and fractional integration in econometrics". *Journal* of Econometrics, 73, 5-59.
- Baillie, R. T. and T. Bollerslev (1994). "Long memory in the forward premium". *Journal of International Money and Finance*, 13, 565-571.
- Geweke, J. and S. Porter-Hudak (1983). "The estimation and application of long memory the series models." *Journal of Time Series Analysis*, 4, pp.221-38.
- Gil-Alana, L. A. and P. M. Robinson (1997). "Testing of Unit Root and Other Nonstationary Hypothesis in Macroeconomic Time Series", *Journal of Econometrics*, 80, pp. 241-268.
- Granger, C. W. J. (1980). "Long memory relationships and the aggregation of dynamic models". *Journal of Econometrics*, 14, 227-238.
- Granger, C. W. J. and R. Joyeux (1980). "An introduction to long memory time series models and fractional differencing". *Journal of Time Series Analysis*, 1, 15-39.

Hosking, J. R. M. (1981). "Fractional differencing". Biometrika, 68, 165-176.

- Hurvich, C. M., R. Deo and J. Brodsky (1998). ``The Mean Squared Error of Geweke and Porter Hudak's Estimator of the Memory Parameter of a Long Memory Time Series", *Journal of Time Series Analysis*, 19, pp. 19-46.
- Kim, C. S. and P. C. B. Phillips (1999). "Log Periodogram Regression: The Nonstationary Case". Cowles Foundation Discussion Paper, Yale University.
- Kim, C. S. and P. C. B. Phillips (1999). "Fully Modified Estimation of Fractional Cointegration Models". Cowles Foundation Discussion Paper, Yale University.
- Kunsch, H. (1986). "Discrimination between monotonic trends and long-range dependence". *Journal of Applied Probability*, 23, 1025-1030.
- Kunsch, H. R. (1987). "Statistical Aspects of Self-Similar Processes", Proceedings of the First World Congress of the Bernoulli Society, Vol. 1, 67-74, VNU Science Press
- Lobato, I. and P.M. Robinson (1996). "Averaged periodogram estimation of long memory". *Journal of Econometrics*, 73, 303-324.
- Mandelbrot, B. B. and J. W. Van Ness (1968). "Fractional Brownian motions, fractional Brownian noises and applications". SIAM Review, 10, 422-437.
- Mandelbrot, B. B. and J. Wallis (1968). "Noah, Joseph and operational hydrology". *Water Resources Research*, 4, 909-918.
- Phillips P. C. B (1999) "Discrete Fourier Transforms of Fractional Processes". Cowles Foundation Discussion Paper, Yale University.
- Phillips P. C. B (1999) "Unit Root Log Periodogram Regression". Cowles Foundation Discussion Paper, Yale University.
- Phillips, P. C. B. and K. Shimotsu (2000) "Local Whittle Estimation in Unit Root and Nonstationary Cases", Cowles Foundation Discussion Paper, Yale University.
- Robinson, P. M. (1978). "Statistical inference for a random coefficient autoregressive model". *Scandanavian Journal of Statistics*, 5, 163-168.
- Robinson, P. M. (1992). "Semiparametric analysis of long-memory time series". Annals of Statistics, 22, 515-539.
- Robinson, P. M. (1994). "Efficient Tests in Nonstationary Hypothesis", *Journal of the American Statistical Association*, 89, pp. 1420-1437.
- Robinson, P. (1995a) "Log periodogram regression of time series with long range dependence". *Annals of Statistics*, 23, 1048-1072.
- Robinson, P. (1995b) "Gaussian Semiparametric Estimation of Long Range Dependence." *Annals of Statistics*, 23, pp.1630-1661.

- Shimotsu K. and P. C. B. Phillips (2001) "Pooled Log Periodogram Regression" (with Katsumi Shimotsu) *Journal of Time Series Analysis*, (forthcoming).
- Shimotsu K. and P. C. B. Phillips (2000) "Modified Local Whittle Estimation of the Memory Parameter in the Nonstationary Case". Cowles Foundation Discussion Paper, Yale University.
- Sowell, F. B. (1986). "Fractionally integrated vector time series". Ph.D. dissertation (Duke University, Durham, NC).
- Sowell, F. B. (1990). "The fractional unit root distribution". Econometrica, 58, 495-505.
- Sowell, F. B. (1992). "Maximum likelihood estimation of stationary univariate fractionally integrated time series models". *Journal of Econometrics*, 53, 165-188.
- Taqqu, M. S. (1975). "Weak convergence to fractional Brownian motion and to the Rosenblatt process". Zeitschrift fur Wahrscheinlichkeitstheorie und Verwandte Gebiete, 31, 287-302.
- Tanaka, K. (1999). "The nonstationary fractional unit root." *Econometric Theory*, 15 pp.549-582.
- Velasco, C. (1999a). "Gaussian Semiparametric Estimation of Non-Stationary Time Series." Journal of Time Series Analysis, 20 pp. 87-127.
- Velasco, C. (1999b). "Non-stationary log-periodogram regression." *Journal of Econometrics*, 91 pp. 325-371.

Velasco, C. (2000). "Non-Gaussian Log Periodogram Regression", Econometric Theory.

Journal of Econometrics, Vol. 73 (1996) [special issue].

#### 14. Bayesian Approaches to Unit Root and Cointegration Analysis

- Chao, J. and P.C.B. Phillips (1994) "Bayesian Model Selection in Partially Nonstationary Vector Autoregressive Processes with Reduced Rank Structure," Yale University, Mimeographed.
- Chao, J. and P.C.B. Phillips (1996) "An Empirical Bayesian Approach to Cointegration Rank Selection and Test of the Present Value Model for Stock Prices" in J. C. Lee and A. Zellner (eds.), *Prediction, Forecasting and Modeling in Statistics and Econometrics*, Springer-Verlag.
- Chao, J. and P.C.B. Phillips (1999) "Model Selection in Partially Nonstationary Vector Autoregressive Processes with Reduced Rank Structure" *Journal of Econometrics*, Vol. 91, No. 2, August 1999, pp. 227-271.
- Econometric Theory, Vol. 10, Nos. 3&4, 1994 [special issue].
- Journal of Applied Econometrics, Vol. 6, No.4, 1991 [special issue].
- Koop, G. (1994) "Recent progress in applied Bayesian econometrics", Journal of Economic Surveys.
- Le Cam, L. and G.L. Yang (1990) Asymptotics in Statistics: Some Basic Concepts. New York: Springer-Verlag.

- Geweke, J. (1988) "The Secular and Cyclical Behavior of Real GNP in Nineteen OECD Countries, 1957–1983," *Journal of Business and Economic Statistics*, 6:479–486.
- Phillips, P.C.B. (1991a) "To Criticize the Critics: An Objective Bayesian Analysis of Stochastic Trends," *Journal of Applied Econometrics*, 6(4):333–364 (with discussion).
- Phillips, P.C.B. (1991b) "Bayesian Routes and Unit Roots: De rebus prioribus semper est disputandum," *Journal of Applied Econometrics*, 435–475.
- Phillips, P.C.B. (1992) "The Long-Run Australian Consumption Function Reexamined: An Empirical Exercise in Bayesian Inference." In C. Hargreaves, ed., Long Run Equilibrium and Macroeconomic Modelling. Cheltenham: Edward Elgar.
- Phillips, P. C. B. (1996). "Econometric Model Determination". *Econometrica*, Vol. 64, No. 4, July 1996, pp. 763-812.
- Phillips, P.C.B. and W. Ploberger (1994) "Posterior Odds Testing for a Unit root with Data-Based Model Selection," *Econometric Theory*, 10:774–808.
- Phillips, P.C.B. and W. Ploberger (1996) "An Asymptotic Theory of Bayesian Inference for Time Series," *Econometrica*, Vol. 64, No. 2, March 1996, 381-413.
- Sims, A. (1988) "Bayesian Skepticism on Unit Root Econometrics," *Journal of Economic Dynamics and Control*, 12:463–474.
- Sims, C.A. and H. Uhlig (1991) "Understanding Unit Rooters: A Helicopter Tour," *Econometrica*, 59(6):1591–1600.
- Zivot, E. and P.C.B. Phillips (1994) "A Bayesian Analysis of Trend Determination in Economic Time Series," *Econometric Reviews*, 13(3): 291–336.

# 15. Spatial Analysis for Nonstationary Data: Densities and Hazard Functions

- Phillips, P. C. B. (1998). "Econometric Analysis of Fisher's Equation", Cowles Foundation Discussion Paper, Yale University.
- Phillips, P. C. B. (1998). "Econometric Analysis of Nonstationary Data". IMF Lectures, November, 1998.
- Phillips, P. C. B. and J. Y. Park (1998). "Nonstationary Density Estimation and Kernel Autoregression" Cowles Foundation Discussion Paper, Yale University.
- Phillips, P. C. B. (2001). "Descriptive Econometrics for Nonstationary Time Series with Empirical Applications". *Journal of Applied Econometrics*.

# 16. Nonlinear Integration and Regression

- 16
- Chang Y., J. Y. Park and P. C. B. Phillips (2001). "Nonlinear Econometric Models with Cointegrated and Deterministically Trending Regressors", *Econometrics Journal*, 4, pp. 1-36.
- Park J. Y. and P. C. B. Phillips (1999). "Asymptotics for Nonlinear Transformations of Integrated Time Series", *Econometric Theory*, 15, pp. 269-298.
- Park J. Y. and P. C. B. Phillips (2000). "Nonstationary Binary Choice Models", *Econometrica*, 68, pp. 1249-1280.
- Park J. Y. and P. C. B. Phillips (2001). "Nonlinear regressions with integrated time series", *Econometrica*, 69, pp. 117-161.

# **17. Nonstationary Panel Data and Cointegration**

- Moon H. R. and P. C. B. Phillips (2000) "Estimation of Autoregressive Roots near Unity using Panel Data" (with Hyungsik Moon), *Econometric Theory*, Vol. 16, No. 6, December, 2000, pp 927-998.
- Phillips P. C. B. and H. R. Moon (2001) "Nonstationary Panel Data Analysis: An Overview of Some Recent Developments" *Econometric Reviews*.
- Phillips P. C. B. and H. R. Moon (1999) "Linear Regression Limit Theory for Nonstationary Panel Data", *Econometrica*, 67, pp.1057-1111.
- Phillips P. C. B. and D. Sul (2003) "Dynamic Panel Estimation and Homogeneity Testing under Cross Section Dependence", 6, pp. 217-259.