Boston University; Department of Economics

ECONOMICS 708: ADVANCED ECONOMETRICS I

Spring 2014

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The aim of the course is to develop familiarity with a wide range of statistical and econometric techniques that have proved to be useful in applied contexts. Theoretical results will be developed as necessary and in order to allow students to apply general principles to their own research problems. Primary emphasis, however, is placed upon applicability, on the ability to understand the techniques in use in the literature, and on acquiring a minimal acquaintance with econometric computing. The material discussed is a reasonable definition of the minimum that a well-trained economics Ph.D. should know. For those of you who are primarily interested in economic theory, the course should give you some idea of the way in which economists attempt to confront theory and evidence.

Prerequisites

Economics 707 or equivalent. Familiarity with calculus, linear (matrix) algebra and basic mathematical statistics is expected. I shall also assume that students are familiar with the general linear regression model, its algebra, and estimation and inference within that framework. (Students for whom this last assumption is not true will have a hard time very quickly and should review the material at once.)

Grading

The course grade will be based on a mid-term (30%) and a final (50%) and 4-5 problem sets (20%). The final will be a 3 hours exam and will cover all material. Parts of the problem sets can be asked in the mid-term or final exams.

Academic Conduct

Students should know and understand the GRS Academic Conduct Code, see http://www.bu.edu/cas/students/graduate/forms-policies-procedures/academic-discipline-procedures/. Any suspected academic misconduct will be reported to the Dean's Office.

Texts and Notes

Good texts to review the basic notions of probability and statistics useful for this course are:

Casella, G. and R. Berger, *Statistical Inferenc*e, Duxbury Press, 2nd ed., 2001.

Gallant, A.R. (1997) *An Introduction to Econometric Theory*, Princeton University Press.

There is no required text, which we will follow closely. The course is based on a set of notes, which will be distributed at the cost of photocopying. However, it is strongly recommend that you complement these notes with one or more of the following textbooks:

Davidson, R. and J. G. MacKinnon (2004) *Econometric Theory and Methods*, Oxford University Press.

Ruud, P.A. (2000), *An Introduction to Classical Econometric Theory*, Oxford University Press.

Hayashi, F. (2000), *Econometrics*, Princeton University Press.

You are also strongly encouraged to supplement the material discussed in class with a good introductory level book that gives an intuitive explanation of the use of the various methods. The one I recommend is:

Stock, J.H. and M.W. Watson (2002), *Introduction to Econometrics*, Addison-Wesley.

Other useful books are:

Gourieroux, C. and A. Monfort (1995) *Statistics and Econometric Models*, Cambridge.

Greene, W. (2003) *Econometrics Analysis*, 5th ed., Prentice Hall.

Judge, G.G., W.E. Griffiths, R.C. Hill and T.C. Lee (1988) *The Theory and Practice of Econometrics*, 2nd ed., Wiley.

At a more advanced and theoretical level, the following books are very useful:

Amemiya, T. (1986), *Advanced Econometrics*, Harvard University Press.

Rao, C.R. (1973), *Linear Statistical Inference and Its Applications*, 2nd ed. New York: Wiley.

Silvey, S.D. (1975), *Statistical Inference*, London: Chapman and Hall.

Cox, D.R. and D.V. Hinkley (1974), *Theoretical Statistics*, London: Chapman and Hall.

White, H. (1984), *Asymptotic Theory for Econometricians*, New York: Academic Press.

Griliches, Z. and M.D. Intriligator, eds., *Handbook of Econometrics*, Volumes 1-3. North-Holland.

Engle, R.F. and D. McFaden (1994), *Handbook of Econometrics*, Volume 4. North Holland.

Gallant, A.R. and H. White (1988), *A Unified Theory of Estimation and Inference for Nonlinear Dynamic Models*, Basil Blackwell.

Godfrey, L.G. (1988), *Misspecification Tests in Econometrics*, Cambridge University Press.

Phillips, P.C.B. and M.R. Wickens (1978), *Exercises in Econometrics*, Volume 1 and 2. Phillip Allen.

An interesting book with economic applications is:

Berndt, E.R. (1991), *The Practice of Econometrics: Classics and Contemporary*, Addison-Wesley.

COURSE OUTLINE

1. **Geometric Interpretation of Least-squares**: vector spaces and projections (motivation, vector spaces, matrices as linear maps, projections, generalized inverses, projection maps in the standard linear model).

2. **Properties of the Least-Squares Projection** (fitted values, residuals, measure of fit, the Frish-Waugh-Lovell Theorem).

3. **The Basic Linear Model; Finite Sample Results** (model and assumptions, properties of the least-squares estimator, the Gauss-Markov Theorem, estimation of the variance of the errors, LUS Residuals, recursive residuals).

4. **Restricted Least-squares** (the restricted OLS estimate, consequence of misspecification, geometric interpretation).

5. **Normal Distribution Theory** (exact distribution of least-squares estimates and test statistics under Normality).

6. **A Brief Review of Asymptotic Results** (convergence in probability, orders of magnitude, convergence in distribution, martingale differences).

7. **The Basic Linear Model; Asymptotic Results** (The Mann-Wald Theorem, consistency, asymptotic Normality; the basic AR(1) model; test statistics and confidence intervals)

8. **Instrumental Variables** (instruments and estimator, the GIVE estimator, two-stage interpretation).

9. **Introduction to Time Series** (preliminaries, stationarity, the autocovariance and autocorrelation function, Wold's Theorem, the first-order autoregressive process, general AR(p) processes, moving-average processes, mixed ARMA processes).

10. **Non-spherical Errors** (properties of OLS, using OLS with corrected standard errors, consistent estimators of variance-covariance matrices robust to serial correlation and heteroskedasticity, the GLS estimator, geometric interpretation of GLS, when is OLS equivalent to GLS? feasible GLS).

11. **Nonlinear Regressions** (basic results, numerical optimization).

12. **Maximum Likelihood Estimation** (the principle of MLE, sufficient statistics, the Cramer-Rao lower bound, asymptotic distribution of the MLE, an information matrix equality, the MLE in the standard linear model, consistent estimates of the information matrix).

13. **Estimation with Serially Correlated Errors** (the covariance matrix of the errors with AR(1) errors, feasible GLS, maximum likelihood procedure, other procedures, extensions to AR(p) errors, estimation with moving-average errors).

14. **Estimation with Heteroskedasticity** (GLS estimation, maximum likelihood procedure).

15. **Multivariate Regressions** (seemingly unrelated regressions, multivariate regressions, goodness of fit in multivariate models).

16. **The Trinity of Test Procedures** (LR, Wald and LM tests, asymptotic distribution, geometric interpretation, when are LM, LR and Wald tests the same? the LM test in least-squares problems).

17. **The Trinity of Tests in the Classical Linear Model** (the Wald, LR and LM tests, a finite sample inequality).

18. **Examples of Test Statistics** (testing for heteroskedascticity: the Breush-Pagan LM test, White's test; testing for autocorrelation: the Durbin-Watson test, test based on recursive residuals, Box-Pierce statistic, LR test, LM test for AR(p) errors).

19. **Other Tests of Misspecification** (Hausman type tests, tests based on nuisance parameters, test for structural change, non-nested hypothesis testing).

20. **Misspecified Models** (basic issues of the quasi-MLE, the Kullback-Leibler distance, asymptotic distribution of the quasi-MLE, hypothesis testing with potential misspecification, the information matrix test for misspecification, simplification of the information matrix test).

21. **Some Pitfalls of Testing Procedures in Nonlinear Contexts** (non-invariance of Wald tests to alternative specifications of the null hypothesis, non-invariance to units of measurements, review of testing procedures in a likelihood framework).

22. **Unit Roots, Cointegration and Spurious Regressions** (an example, unit roots, differenced versus trend stationary models, testing for a unit root, spurious regression, cointegration, error correction models, testing for cointegration).

23. **Simultaneous Equations Models** (the structural form, the reduced form, the identification problem, identification in terms of the reduced form, more on identification: basic concepts, conditions for two structures to be observationally equivalent, conditions for identifications, identification using within equation linear restrictions, identification with cross-equations restrictions).

24. **Estimation of Simultaneous Equations Models** (the inconsistency of OLS, two-stage least-squares estimator and its asymptotic distribution, three stage least-squares estimator and its asymptotic distribution).

25. **Full Information Maximum Likelihood of Simultaneous Equations Models** (the likelihood function, derivation of the FIML equations, difference with 3SLS, asymptotic distribution, testing the validity of overidentifying restrictions).

26. **Generalized Methods of Moments** (if time permits).

27. **Indirect Inference** (if time permits).

Selected Readings.

0. Review of Matrix Algebra: Ruud, Appendix C.

Maddala (1977), *Econometrics*, McGraw Hill, Appendix A, 434-447.

Dhrymes, P.J. (1984), *Mathematics for Econometrics*. Springer Verlag.

Theil, H. (1983), "Linear algebra and matrix methods in econometrics," Chapter 1 in *Handbook of Econometrics*, Vol. 1, pp 3-64.

Magnus, J. (1988), *Linear Structures*, Oxford University Press.

Magnus, J.R. and H. Neudeker (1988), *Matrix Differential Calculus with Applications in Statistics and Econometrics*, Wiley.

1. Geometric Interpretation of Least-squares: DM, ch. 2.1-2.3; Ruud, ch. 2.

2. Properties of the Least-Squares Projection: DM, ch. 3.4-3.5, 3.6, 3.8.

3. The Basic Linear Model; Finite Sample Results: DM, ch. 3.1-3.5; Ruud, ch. 6-9.

Harvey, A.C. (1981), *The Econometric Analysis of Time Series*, Philip Allan, Sec. 2.6-2.7.

Brown, R.L., J. Durbin and J.M. Evans (1975), "Techniques for testing the constancy of regression relationship over time," *Journal of the Royal Statistical Society* B-37, 149-192.

Dufour, J.M. (1982), "Recursive stability analysis of linear regression relationships: An exploratoy methodology," *Journal of Econometrics* 19, 31-76.

4. Restricted Least-squares: Ruud, ch. 4.; DM, ch. 3.7.

5. Normal Distribution Theory: DM., 4.1-4.4, 4.7, 5.4; Ruud, ch. 10-11.

6. A Brief Review of Asymptotic Results: DM, ch 4.5; Ruud, ch. 13.4.

Fuller, W. (1976), *Introduction to Time Series Analysis*, Wiley, Ch.5.

7. The Basic Linear Model; Asymptotic Results: DM, ch. 4.5, 5.2.

Thurman, W.N. (1989), "Unconditional asymptotic results for simple linear regression," *The American Statistician*, 43: 148-152.

8. Instrumental Variables: DM, ch. 8.1-8.4; Ruud, ch. 20.

Angrist, J.D. and A.B. Krueger (2001), "Instrumental variables and the search for identification: from supply and demand to natural experiments", *Journal of Economic Perspectives* 15 (4), 69-85.

Stock, J.H., M. Yogo and J. Wright (2002), "A survey of weak instruments and weak identification in generalized method of moments," *Journal of Business and Economic Statistics* 20, 518-529.

9. Introduction to Time Series: DM, ch. 7.6, 13.2.

Hamilton J.D. (1994), *Time Series Analysis*, Princeton University Press, ch. 1-3.

Additional references: See course outline for ECN 712.

10. Non-spherical Errors: DM, ch. 7.1-7.6, 5.5.

Andrews, D.W.K. (1991), "Heteroskedasticity and autocorrelation consistent covariance matrix estimation," *Econometrica* 59, 817-858.

Milliken, G.A. and M. Albohali (1984), "On necessary and sufficient conditions for ordinary least squares estimators to be best linear unbiased estimators," *The American Statistician* 38, 298-299.

11. Nonlinear Regressions: DM, ch. 6; Ruud, ch. 16.

Amemiya, T. (1984), "Nonlinear regression models," in *Handbook of Econometrics*, vol. 1, ch. 6.

Quandt, R.E. (1983), "Computational problems and methods," in *Handbook of Econometrics*, vol. 1, 699-764.

McCullough, B.D. and H.D. Vinod (2003), "Verifying the solution from a nonlinear solver: a case study," *American Economic Review* 93, 873-892.
+
Shakar, R. and B. Nalebuff (2004), "Verifying the solution from a nonlinear solver: a case study: comment," *American Economic Review* 94, 382-390.
+
McCullough, B.D. and H.D. Vinod (2003), "Verifying the solution from a nonlinear solver: a case study: reply," *American Economic Review* 94, 391-396.

12. Maximum Likelihood Estimation: DM, ch. 10; Ruud, ch. 14-15.

13. Estimation with Serially Correlated Errors: DM, ch. 7.8; Ruud, ch. 19.

14. Estimation with Heteroskedasticity: DM, ch. 7.5; Ruud, ch. 18.

15. Multivariate Regressions: DM, ch. 12; Ruud, ch. 26.2.

Buse, A. (1979), "Goddness of fit in the SURE model," *Journal of Econometrics* 10, 109-114.

McElroy, M. (1977), "Goodness of fit for seemingly unrelated regressions," *Journal of Econometrics* 6, 381-387.

Srivasta, V. and T. Dwivedi (1979), "Estimation of seemingly unrelated regressions: a brief survey," *Journal of Econometrics* 6, 381-387.

16. The Trinity of Test Procedures: DM, ch. 4.1-4.5, 10.6; Ruud, ch. 11, 17.1-17.3.

Buse, A. (1982), "The likelihood ratio, Wald and Lagrange multiplier tests: An expository note," *The American Statistician*, 153-157.

Engle, R.F. (1984), "Wald, likelihood ratio and Lagrange multiplier tests in econometrics," *Handbook of Econometrics*, Vol. III, Ch. 13.

Breusch, T.S. and A.R. Pagan (1980), "The Lagrange multiplier test and its application to model specification in econometrics," *Review of Economic Studies* 47, 239-254.

17. The Trinity of Tests in the Classical Linear Model: DM, ch. 4.1-4.5.

Breusch, T.S. (1979), "Conflict among criteria for testing hypotheses: extensions and comments," *Econometrica* 47, 203-207.

18. Examples of Test Statistics

1) Testing for heteroskedasticity: DM, ch. 7.5; Ruud, ch. 18.3.

Breusch, T.S. and A.R. Pagan (1979), "A simple test for heteroskedasticity and random coefficient variation," *Econometrica* 47, 1287-1294.

2) Testing for serial correlation: DM, ch. 7.7; Ruud, ch. 19.4.

Engle, R.F. (1982), "A general approach to Lagrange multiplier diagnostics," *Journal of Econometrics* 20, 83-104.

Godfrey, L.G. (1978), "Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables," *Econometrica* 46, 1293-1302.

19. Other Tests of Misspecification: DM, ch. 8.7, 15.1-15.4; Ruud, 22.3.

Hausman, J.A. (1978), "Specification tests in econometrics," *Econometrica* 46, 1251-1272.

Holly, A. (1982), "A remark on Hausman's specification test," *Econometrica* 50, 749-760.

Rudd, P.A. (1984), "Tests of specification in econometrics," *Econometric Review* 3, 211-242.

Pagan, A.R. (1984), "Model evaluation by variable addition," in D.F. Hendry and K.F. Wallis, eds., *Econometrics and Quantitative Economics* (Oxford: Blackwell).

Pagan, A.R. and A.D. Hall (1983), "Diagnostic tests as residual analysis," *Econometric Reviews* 2, 159-218.

Lancaster, T. (1984), "The covariance matrix of the information matrix test," *Econometrica* 52, 1051-1054.

Chesher, A. (1983), "The information matrix test; simplified calculation via a score test interpretation," *Economics Letters* 13, 45-48.

White, H. (1982), "Maximum likelihood estimation of misspecified models," *Econometrica* 50, 1-26.

White, H. (1980), "A heteroskadasticity-consistent cavariace matrix estimator and a direct test for hetroskedasticity," *Econometrica* 48, 817-838.

MacKinnon, J. (1983), "Model specification tests against non-nested alternatives," *Econometric Reviews* 2, 85-110.

Davidson, R. and J. MacKinnon (1981), "Several tests for model specification in the presence of alternative hypotheses," *Econometrica* 49, 781-793.

McAleer, M. (1984), "Specification tests for separate models: A survey," in D. Giles and M.A. King, eds., *Specification Analysis in the Linear Model* (Routledge and Kegan Paul).

20. **Misspecified Models**

White, H. (1982), "Maximum likelihood estimation of misspecified models," *Econometrica* 50, 1-26.

White, H. (1980), "A heteroskadasticity-consistent cavariace matrix estimator and a direct test for hetroskedasticity," *Econometrica* 48, 817-838.

21. Some Pitfalls of Testing Procedures in Nonlinear Contexts: Ruud, ch. 17.4.

Gregory, A. and M. Veall (1985), "Formulating Wald tests of nonlinear restrictions," *Econometrica* 53, 1465-1468.

Lafontaine, F. and K. White (1986), "Obtaining any Wald statistic you want," *Economics Letters* 21, 35-40.

Dagenais, M. and J.M. Dufour (1996), "Invariance, nonlinear models and asymptotic tests," *Econometrica* 59, 1601-1616.

Breusch, T.S. and P. Schmidt (1988), "Alternative forms of the Wald test: How long is a piece of string," *Communication in Statistics, Theory and Methods* 17(8), 2789-2795.

22. Unit Roots, Cointegration and Spurious Regressions: D-M, ch 20.

Hendry, D. (1980), "Econometrics: Alchemy or science?," *Economica* 47, 387-406.

Hansen, B.E. (2001), "The new econometrics of structural change: dating breaks in U.S. labor productivity," *Journal of Economic Perspectives* 15 (4), 117-128.

Granger, C.W. and P. Newbold (1974), "Spurious regressions in econometrics," *Journal of Econometrics* 2, 111-120.

Campbell, J.Y. and P. Perron (1991), "Pitfalls and opportunities: What macroeconmists should know about unit roots," *NBER Macroeconomics Annual* Vol. 6, O.J. Blanchard and S. Fisher (eds), 141-201.

Stock, J.H. and M.W. Watson (1988), "Variable trends in economic time series," *Journal of Economic Perspective* 2, 147-174.

Nelson, C.R. and C.I. Plosser (1982), "Trends and random walks in macroeconomic time series," *Journal of Monetary Economics* 10, 139-162.

Perron, P. (1989), "The great crash, the oil price shock and the unit root hypothesis," *Econometrica* 57, 1361-1402.

Hendry, D.F. (1986), "Econometric modelling with cointegrated variables: An overview," *Oxford Bulletin of Economics and Statistics* 48, 201-212.

Granger, C.W. (1986), "Developments in the study of cointegrated economic variables," *Oxford Bulletin of Economics and Statistics* 48, 213-228.

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.

Engle, R.F. and C.W. Granger (1987), "Co-integration and error correction: Representation, estimation and testing," *Econometrica* 55, 251-276.

Additional references: See course outline for EC 712.

23-24-25. Simultaneous Equations Models: DM, ch. 12.4-12.8; Ruud, ch. 26.

Hendry, D.F. (1976), "The structure of simultaneous equations estimators," *Journal of Econometrics* 4, 51-88.

Hausman, J.A. (1981), "Specification and estimation of simultaneous equations models," *Handbook of Econometrics*, Vol. I, Ch.7.

Hausman, J.A. (1975), "An instrumental variable approach to full information estimators," *Econometrica* 43, 727-738.

Hsiao, C. (1983), "Identification," in *Handbook of Econometrics*, Vol. I, Ch. 4.

26. Generalized Methods of Moments: DM, ch. 9; Ruud, ch. 21-22.

Hansen, L.P. (1982), "Large sample properties of generalized method of moments estimators," *Econometrica* 50, 1029-1054.

Hansen, L.P. and K.J. Singleton (1892), "Generalized instrumental variable estimation of nonlinear rational expectations models," *Econometrica* 50, 1269-1296.