資料包絡分析與應用

DATA ENVELOPMENT ANALYSIS AND APPLICATIONS

國立臺灣大學農業經濟研究所

課程編號: 627 M4810

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學分:3 全年或半年:半年 必修或選修:選修

授課對象:碩士班、博士班研究生及相關研究單位專家學者

軟體程式:

(1) GAMS: Release 2.25, 1992, Washington, D.C.: GAMS Development Corp. 本程式置於臺灣大學農業經濟學研究所電腦室,請向電腦室 吳信東先 生申請使用。

評分標準:(1) 課堂討論佔學期總分 20%

- (2) 習題作業(或期中考試)佔學期總分40%
- (3) 期末考試(或期末報告)佔學期總分40%

授課目的:

- 1) 從公理性架構(Axiomatic Framework)探討生產經濟學(Production Theory)基本理論
- 強調在應用生產經濟領域,無效率(Inefficiency)現象的普遍存在及 其測度方法
- 1) 介紹Data Envelopment Analysis (DEA)相關文獻、理論架構及其應用
- 介紹非意欲產出(Undesirable Outputs)的概念、相關文獻、理論架構 及其應用
- 3) Malmquist 總要素生產力的介紹、測度與拆解及實例應用與說明
- 熟悉GAMS 相關軟體程式的操作及其在生產經濟學的應用

主要用書:

Fare, R., S. Grosskopf and C.A. K. Lovell (1985), *The Measurement of Efficiency of Production*, Boston: Kluwer Academic Publishers. [HB241.F335]

Cooper, W.W., L. M. Seiford and K. Tone (1999), Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software, Boston: Kluwer Academic Publishers. [HA31.38.C66]

Fare, R., S. Grosskopf and C.A. K. Lovell (1994), *Production Frontiers*, Cambridge: Cambridge University Press. [HB241.F336]

参考用書:

Fare, R. (1988), *Fundamentals of Production Theory*, Berlin: Springer-Verlag.
Fare, R. and S. Grosskopf (1994), *Cost and Revenue Constrained Production*, New York: Springer-Verlag, Bilkent University Lecture Series.

Fare, R. and D. Primont (1995), *Multi-Output Production and Duality: Theory and Applications*, Boston: Kluwer Academic Publishers.

Fare, R. and S. Grosskopf (1996), *Intertemporal Production Frontiers: With Dynamic DEA*, Boston: Kluwer Academic Publishers.

授課大綱

I. The Measurement of Productive Efficiency:

Introduction

- Coelli, Timothy J., D.S. Prasada Rao, Christopher J. O'Donnell and George E. Battese, *An Introduction to Efficiency and Productivity Analysis*, Second Edition, New York: Springer Science+Business Media, Inc., 2005. [HB241.C64] Chapters 1, 2, and 3.
- Kumbhakar, S.C. and C.A.K. Lovell (2000), *Stochastic Frontier Analysis*. New York: Cambridge University Press. Chs. 1 & 2.
- Lovell, C.A.K. (1993), "Production Frontiers and Productive Efficiency," Chapter 1 in H. O. Fried, C. A. K. Lovell and S. S. Schmidt, eds., *The Measurement* of *Productive Efficiency: Techniques and Applications*. New York: Oxford University Press.

<u>The Mathematical Programming Approach: Data Envelopment</u> <u>Analysis</u>

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8) Measures of Scale Efficiency

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- 8.5 Linear Programming Example
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9) Towards Empirical Implementation

- 9.0 Introduction
- 9.1 Summary of the Main Results
- 9.2 Unfinished Business
- 9.3 Toward Empirical Implementation

10) References

- Banker, R.D. (1993), "Maximum Likelihood, Consistency and Data Envelopment Analysis: A Statistical Foundation," *Management Science*, 39:10 (October), 1265-73.
- Banker, R.D. (1996), "Hypothesis Tests Using Data Envelopment Analysis," *Journal of Productivity Analysis*, 7:2/3 (July), 139-59.
- Barr, R.S., L.M. Seiford and T.F. Siems (1993), "An Envelopment-Analysis Approach to Measuring the Managerial Efficiency of Banks," *Annals of Operations Research*, 45, 1-19.
- Barr, R.S., L.M. Seiford and T.F. Siems (1994), "Forecasting Bank Failure: A Non-Parametric Frontier Estimation Approach," *Recherches Economiques de Louvain*, 60:4, 417-29.
- Branson, J. and C.A.K. Lovell (2001), "A Growth Maximising Tax Structure for New Zealand," *International Tax and Public Finance*, 8:2 (March), 129-46.
- Coelli, Timothy J., D.S. Prasada Rao, Christopher J. O'Donnell and George E. Battese, An Introduction to Efficiency and Productivity Analysis, Second Edition, New York: Springer Science+Business Media, Inc., 2005. [HB241.C64] Chapters 5, 6.
- Cummins, J.D., M.A. Weiss and H. Zi (1999), "Organizational Form and Efficiency: The Coexistence of Stock and Mutual Property Liability Insurers," *Management Science*, 45:9 (September), 1254-69.
- De Borger, B. and K. Kerstens (2000), "What is Known About Municipal Efficiency? The Belgian Case and Beyond," Chapter 12 in J. L. T. Blank, ed., *Public Provision and Performance: Contributions from Efficiency and Productivity Measurement.* Amsterdam: North - Holland.
- Fried, H.O., S.S. Schmidt and S. Yaisawarng (1999), "Incorporating the Operating Environment into a Nonparametric Measure of Technical Efficiency," *Journal* of Productivity Analysis, 12:3 (November), 249-67.
- Grosskopf, S., K.J. Hayes, L.L. Taylor and W.L. Weber (1999), "Anticipating the Consequences of School Reform: A New Use of DEA," *Management Science*, 45:4 (April), 608-20.

- Lovell, C.A.K. (1994), "Linear Programming Approaches to the Measurement and Analysis of Productive Efficiency," *Top*, 2:2, 1-50.
- Lovell, C.A.K. and J.T. Pastor (1997), "Target Setting: An Application to a Bank Branch Network," *European Journal of Operational Research*, 98, 290-99.
- McCarty, T.A. and S. Yaisawarng (1993), "Technical Efficiency in New Jersey School Districts," Chapter 10 in Fried, Lovell & Schmidt, eds.
- Pastor, J.T., J.L. Ruiz and I. Sirvent (2000), "A Statistical Test for Nested Radial DEA Models," Working Paper, Departamento de Estadística y Matemática Aplicada, Universidad Miguel Hernández, 03202 Elche (Alicante), Spain, forthcoming in *Operations Research*.
- Siems, T.F. and R.S. Barr (1998), "Benchmarking the Productive Efficiency of U. S. Banks," *Financial Industry Studies*. Dallas: Federal Reserve Bank of Dallas (December), 11-24.
- Vanden Eeckaut, P., H. Tulkens and M.-A. Jamar (1993), "Cost Efficiency in Belgian Municipalities," Chapter 12 in Fried, Lovell & Schmidt, eds.

The Econometric Approach: Stochastic Frontier Analysis

- Battese, G.E. and T.J. Coelli (1992), "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India," *Journal of Productivity Analysis*, 3:1/2 (June), 153-69.
- Battese, G.E. and T.J. Coelli (1995), "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data," *Empirical Economics*, 20, 325-32.
- Berger, A.N. and L. J. Mester (1997), "Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions?" *Journal of Banking and Finance*, 21:7 (July), 895-947.
- Coelli, T., S. Perelman and E. Romano (1999), "Accounting for Environmental Influences in Stochastic Frontier Models: With Application to International Airlines," *Journal of Productivity Analysis*, 11:3 (June), 251-73.
- Coelli, Timothy J., D.S. Prasada Rao, Christopher J. O'Donnell and George E. Battese, *An Introduction to Efficiency and Productivity Analysis*, Second Edition, New York: Springer Science+Business Media, Inc., 2005. [HB241.C64] Chapters 8, 9, 10.
- Greene, W.H. (1993), "The Econometric Approach to Efficiency Analysis," Chapter 2 in Fried, Lovell & Schmidt, eds.
- Grosskopf, S., K.J. Hayes, L.L. Taylor and W.L. Weber (1997), "Budget-Constrained Frontier Measures of Fiscal Equality and Efficiency in Schooling," *Review of Economics and Statistics*, 79:1 (February), 116-24.
- Hunt-McCool, J.C. and R.S. Warren, Jr. (1993), "Earnings Frontiers and Labor Market Efficiency," Chapter 5 in Fried, Lovell & Schmidt, eds.
- Kumbhakar, S.C. (1997), "Modeling Allocative Inefficiency in a Translog Cost Function and Cost Share Equations: An Exact Relationship," *Journal of Econometrics*, 76, 351-56.
- Lozano Vivas, A. (1997), "Profit Efficiency for Spanish Savings Banks," *European Journal of Operational Research*, 98:2 (April 16), 381-94.
- Polachek, S.W. and J. Robst (1998), "Employee Labor Market Information: Comparing Direct World of Work Measures of Workers' Knowledge to Stochastic Frontiers," *Labour Economics*, 5:2 (June), 231-42.

<u>Comparisons of Econometric and Mathematical Programming</u> <u>Analyses</u>

- Bauer, P.W., A.N. Berger, G.D. Ferrier and D.B. Humphrey (1998), "Consistency Conditions for Regulatory Analysis of Financial Institutions: A Comparison of Frontier Efficiency Methods," *Journal of Economics and Business*, 50:2 (March/April), 85-114.
- Cummins, J.D. and H. Zi (1998), "Comparison of Frontier Efficiency Methods: An Application to the U.S. Life Insurance Industry," *Journal of Productivity Analysis*, 10:2 (October), 131-52.

II. The Measurement of Productivity Change

1) Background

- Coelli, Timothy J., D.S. Prasada Rao, Christopher J. O'Donnell and George E. Battese, *An Introduction to Efficiency and Productivity Analysis*, Second Edition, New York: Springer Science+Business Media, Inc., 2005. [HB241.C64] Chapter 11.
- Diewert, W. E. (1992), "The Measurement of Productivity," *Bulletin of Economic Research* 44:3, 163-98.
- Griliches, Z. (1996), "The Discovery of the Residual: A Historical Note," *Journal* of Economic Literature 34:3 (September), 1324-30.
- Solow, R.M. (1957), "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* 39:3 (August), 312-20.

2) The Econometric Approach

- Atkinson, S.E. and C. Cornwell (1998), "Estimating Radial Measures of Productivity Growth: Frontier vs. Non-Frontier Approaches," *Journal of Productivity Analysis*, 10:1 (July), 35-46.
- Atkinson, S.E., C. Cornwell and O. Honerkamp (2000), "Measuring and Decomposing Productivity Change: Stochastic Distance Function Estimation vs. DEA," Working Paper, Department of Economics, University of Georgia, Athens, GA 30602.
- Baltagi, B.H. and J.M. Griffin (1988), "A General Index of Technical Change," *Journal of Political Economy*, 96:1 (February), 20-41.
- Bauer, P.W. (1990), "Decomposing TFP Growth in the Presence of Cost Inefficiency, Nonconstant Returns to Scale, and Technological Progress," *Journal of Productivity Analysis*, 1:4 (June), 287-99.
- Berndt, E.R. and B. Hansson (1992), "Measuring the Contribution of Public Infrastructure Capital in Sweden," *Scandinavian Journal of Economics*, 94 (Supplement), S151-S168.
- Caves, D.W., L.R. Christensen and J.A. Swanson (1980), "Productivity in US Railroads, 1951-1974," *Bell Journal of Economics*, 11 (Spring), 177-81.
- Caves, D.W., L.R. Christensen and J.A. Swanson (1981), "Productivity Growth, Scale Economies and Capacity Utilization in US Railroads, 1955-74," *American Economic Review*, 71:5 (December), 994-1002.
- Coelli, T. (1996), "Measurement of Total Factor Productivity Growth and Biases in Technological Change in Western Australian Agriculture," *Journal of Applied Econometrics*, 11, 77-91.

- Denny, M., M. Fuss and L. Waverman (1981), "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications," in T. G. Cowing and R. Stevenson, eds., *Productivity Measurement in Regulated Industries.* New York: Academic Press.
- Karagiannis, G. and G. Mergos (2000), "Total Factor Productivity Growth and Technical Change in a Profit Function Framework," *Journal of Productivity Analysis*, 14:1 (July), 31-51.
- Kumbhakar, S.C. and C.A.K. Lovell (2000), *Stochastic Frontier Analysis*. New York: Cambridge University Press. Ch. 8.

3) The Mathematical Programming: Malmquist Indexes

- Balk, B.M. (1995), "On Approximating the Indirect Malmquist Productivity Indices by Fisher Indices," *Journal of Productivity Analysis*, 6:3 (September), 195-200.
- Bjurek, H. (1996), "The Malmquist Total Factor Productivity Index," *Scandinavian Journal of Economics*, 98:2, 303-13.
- Bjurek, H., F.R. Førsund and L. Hjalmarsson (1998), "Malmquist Productivity Indexes: An Empirical Comparison," Ch. 5 in R. Färe, S. Grosskopf and R. R. Russell, eds, *Index Numbers: Essays in Honour of Sten Malmquist*. Boston: Kluwer Academic Publishers.
- Färe, R., S. Grosskopf and C. A. K. Lovell (1994), *Production Frontiers*. New York: Cambridge University Press. Ch. 9.
- Fare, R., S. Grosskopf, M. Norris, and Z. Zhang, "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries." *American Economic Review*, March 1994, 84(1): 66-83.
- Fare, R., S. Grosskopf, and M. Norris, "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Reply." *American Economic Review*, December 1997, 87(5): 1040-1043.
- Färe, R., S. Grosskopf and P. Roos (1998), "Malmquist Productivity Indexes: A Survey of Theory and Practice," Ch. 3 in R. Färe, S. Grosskopf and R. R. Russell, eds., *Index Numbers: Essays in Honour of Sten Malmquist*. Boston: Kluwer Academic Publishers. (pp. 127-151 only).
- Färe, R., E. Grifell-Tatjé, S. Grosskopf and C. A. K. Lovell (1997), "Biased Technical Change and the Malmquist Productivity Index," *Scandinavian Journal of Economics*, 99:1, 119-27.
- Färe, R., S. Grosskopf and C.A.K. Lovell (1992), "Indirect Productivity Measurement," *Journal of Productivity Analysis*, 2:4 (February), 283-98.
- Fuentes, H., E. Grifell-Tatjé and S. Perelman (2001), "A Parametric Distance Function Approach for Malmquist Index Estimation," *Journal of Productivity Analysis*, 15:2 (March), 79-94.
- Glass, J.C., D.G. McKillop and G. O'Rourke (1998), "A Cost Indirect Evaluation of Productivity Change in UK Universities," *Journal of Productivity Analysis*, 10:2 (October), 153-75.
- Grifell-Tatjé, E. and C.A.K. Lovell (1995), "A Note on the Malmquist Productivity Index," *Economics Letters*, 47:2 (February), 169-75.
- Ray, R.C., and E. Desli, "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Comment." *American Economic Review*, December 1997, 87(5): 1033-1039.

III. Efficieny, Productivity and the Environment

- Ball, V.E., C.A.K. Lovell, H. Luu and R. Nehring (2001), "Incorporating Environmental Impacts in the Measurement of Agricultural Productivity Growth," Working Paper, Department of Economics, University of Georgia, Athens, GA 30602, USA.
- Berman, E. and L.T.M. Bui (1998), "Environmental Regulation and Productivity: Evidence from Oil Refineries," Working Paper No.W6776, National Bureau of Economic Research, Cambridge, MA 02138.
- Bradford, D.F., R. Schlieckert and S. H. Shore (2000), "The Environmental Kuznets Curve: Exploring a Fresh Specification," Working Paper No. W8001, National Bureau of Economic Research, Cambridge, MA 02138.
- Brännlund, R., R. Färe and S. Grosskopf (1995), "Environmental Regulation and Profitability: An Application to Swedish Pulp and Paper Mills," *Environmental and Resource Economics*, 6:1, 23-36.
- Chang, Ching-Cheng, "The Nonparametric Risk-Adjusted Efficiency Measurement: An Application to Taiwan's Major Rural Financial Intermediaries." *American Journal of Agricultural Economics*, 81(Nov. 1999): 902-913.
- Christainsen, G.B. and R.H. Haveman (1981), "Public Regulations and the Slowdown in Productivity Growth," *American Economic Review*, 71:2 (May), 320-25.
- Chung, Y.H., R. Färe and S. Grosskopf (1997), "Productivity and Undesirable Outputs: A Directional Distance Function Approach," *Journal of Environmental Management*, 51, 229-40.
- Färe, R., S. Grosskopf, C.A.K. Lovell and C. Pasurka (1989), "Multilateral Productivity Comparisons When Some Outputs are Undesirable: A Nonparametric Approach," *Review of Economics and Statistics*, 71:1 (February), 90-98.
- Färe, R., S. Grosskopf, C.A.K. Lovell and S. Yaisawarng (1993), "Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach," *Review of Economics and Statistics*, 75:2 (May), 374-80.
- Gollop, F.M. and M.J. Roberts (1983), "Environmental Regulations and Productivity Growth: The Case of Fossil-fueled Electric Power Generation," *Journal of Political Economy*, 91:4 (August), 654-74.
- Pittman, R.W. (1983), "Multilateral Productivity Comparisons with Undesirable Outputs," *Economic Journal*, 93 (December), 883-91.
- Reinhard, S., C.A.K. Lovell and G. Thijssen (1999), "Econometric Estimation of Technical and Environmental Efficiency: An Application to Dutch Dairy Farms," *American Journal of Agricultural Economics*, 81:1 (February), 44-60.
- Repetto, R. (1990), "Environmental Productivity and Why it is So Important," *Challenge*, (September/October), 33-38.
- 游明敏、徐世勳(2001)。<考慮航空噪音下國內機場經營績效及投入擁擠現 象之研究>,《台灣經濟學會年會論文集》,2001年,第121-149頁

IV. Productivity and Profitability

- Althin, R., R. Färe and S. Grosskopf (1996), "Profitability and Productivity Changes: An Application to Swedish Pharmacies," *Annals of Operations Research*, 66, 219-30.
- Grafton, R.Q., D. Squires and K.J. Fox (2000), "Private Property and Economic Efficiency: A Study of a Common-Pool Resource," *Journal of Law and Economics*, 43:2 (October), 679-714.
- Grifell-Tatjé, E. and C.A.K. Lovell (1999), "Profits and Productivity," *Management Science*, 45:9 (September), 1177-93.
- Grifell-Tatjé, E. and C.A.K. Lovell (2000), "Cost and Productivity," *Managerial and Decision Economics*, 21:1 (January/February), 19-30.
- Han, S.-H. and A. Hughes (1999), "Profit Composition Analysis," Working Paper TRP 99-5, New South Wales Treasury, Governor Macquarie Tower, 1 Farrer Place, Sydney, NSW 2000, Australia.
- Salerian, J. and A. Coleman (2000), "Integrating Comparisons of Total Factor Productivity and Price Performance of Industries and Firms Using Ideal Törnqvist Indexes," Productivity Commission, Melbourne, VIC 8003, Australia.
- Salerian, J. and A. Coleman (2000), "Productivity and Profitability: Measuring the Linkages," Working Paper, Productivity Commission, Melbourne, VIC, Australia.
- Waters II, W.G. and J. Street (1998), "Monitoring the Performance of Government Trading Enterprises," *Australian Economic Review*, 31:4 (December), 357-71.
- Waters II, W.G. and M.W. Tretheway (1999), "Comparing Total Factor Productivity and Price Performance - Concepts and Application to Canadian Railways," *Journal of Transport Economics and Policy*, 33:2, 209-20.

V. Productivity and Regulation

- Agrell, P. and P. Bogetoft (2000), "Should Regulators Use DEA?" presentation, Department of Economics, The Royal Agricultural University, Copenhagen, Denmark.
- Bernstein, J.I. (2000), "Price Cap Regulation and Productivity Growth," *International Productivity Monitor*, 1:1 (Fall), 23-28.
- Diewert, W.E. and K.J. Fox (2000), "Incentive Indexes for Regulated Industries," *Journal of Regulatory Economic,s* 17:1 (February), 5-24.
- Diewert, W.E. (1993), "Index Number Issues in Incentive Regulation," Discussion Paper No. 93-06, Department of Economics, University of British Columbia, Vancouver, BC V6T 1Z1, Canada.
- Kittelsen, S.A.C. (1999), "Using DEA to Regulate Norwegian Electricity Distribution Utilities," presentation at Sixth European Workshop on Efficiency and Productivity Analysis, Copenhagen, Denmark.

VI. Productivity Growth Measurement with Time Series Data

Banker, R.D., and A. Maindiratta (1988), "Non-parametric Analysis of Technical and Allocative Analysis Efficiencies in Production," *Econometrica*, 56, 1315-32.

- Chavas, J.P. and T.L. Cox (1997), "Production Analysis: A Non-parametric Time Series Application to U.S. Agriculture," *Journal of Agricultural Economics*, 48, 330-348.
- Hailu, A. and T. S. Veeman (2001), "Non-parametric Productivity Analysis with Undersirable Outputs: An Application to the Canadian Pulp and Paper Industry," *American Journal of Agricultural Economics*, 83(3), 605-616.
- Lynde, C. and J. Richmond (1999), "Productivity and Efficiency in the UK: a Time Series Application to DEA," *Economic Modelling*, 16, 105-122.

VII. Other Applications

- Chen, Yao (2003), "A Non-radial Malmquist Productivity Index with an Illustrative Application to Chinese Major Industries," *International Journal of Production Economics*, 83, 27-35.
- Fried, H.O., C.A.K. Lovell, S.S. Schmidt and S. Yaisawarng (2002), "Accounting for Environmental Effects and Statistical Noise in Data Envelopment Analysis," *Journal of Productivity Analysis*, 17, 157-174.
- Whiteman, John (1999), "The Potential Benefits of Hilmer and Related Reforms: Electricity Supply." *Australian Economic Review*, 32(1): 17-30.