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The Productivity Analysis Research Network, Odense

SECOND EUROPEAN WORKSHOP

on

**EFFICIENCY AND PRODUCTIVITY MEASUREMENT
(METHODOLOGY AND APPLICATIONS)**

October 25 & 26, 1991

Scientific Committee

Finn FØRSUND, University of Oslo
Wolfgang HÄRDLE, CORE, Université Catholique de Louvain
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PROGRAM

CENTER FOR OPERATIONS RESEARCH AND ECONOMETRICS
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SECOND EUROPEAN WORKSHOP ON EFFICIENCY AND PRODUCTIVITY MEASUREMENT
Methodology and Applications
Louvain-La-Neuve, October 25-26, 1991

Friday October 25 — Morning sessions

Chair : Henry TULKENS

- 9:00 "Opening Remarks"
Professor Heraklis POLEMARCHAKIS, Research Director of CORE
- 9:05 Peter HALL, Australian National University, Canberra,
Wolfgang HÄRDLE, CORE, and Leopold SIMAR, CORE
"Iterated Bootstrap with Applications to Frontier Models"
Discussant: Jacques MAIRESSE, ENSAE, Paris
- 10:00 Julien van den BROECK, Universiteit Antwerpen, Gary KOOP, Boston University,
Jacek OSIEWALSKI, Academy of Economics, Krakow and
Mark STEEL, Katholieke Universiteit Brabant, Tilburg
"Stochastic Frontier Models : A Bayesian Perspective"
Discussant: Jacques DREZE, CORE
- 11:00 Coffee break
- 11:30 Knox LOVELL, University of North Carolina at Chapel Hill
"Resources and Functionings : A New View of Inequality in Australia"
Discussant: Louis GEVERS, Facultés Universitaires N.D. de la Paix, Namur

12:30 Lunch at "La Sablonnière"

Friday October 25 — Afternoon sessions

Chair : Niels Christian PETERSEN

- A. *Malmquist Indices and Frontier Shifts:*
- 14:00 Finn FØRSUND, University of Oslo
"The Malmquist Productivity Index"
- 14:30 Rolf FÅRE, Southern Illinois University at Carbondale
"Malmquist Productivity Indexes and Technical Change"
- 15:30 Henry TULKENS and Philippe VANDEN EECKAUT, CORE
"Non-Parametric Measures of Efficiency, Progress and Regress"
- 15:30 Coffee break
- B. *Education:*
- 16:00 Shawna GROSSKOPF, Southern Illinois University at Carbondale
"Teacher Salaries and Teacher Productivity"
- 16:30 Hans DE GROOT, I.O.O., The Hague and
René GOUDRIAAN, Erasmus University, Rotterdam
"Scale and Efficiency in Higher Education :
A comparison of Parametric and Non-Parametric Approaches"
Discussant: Kimberly ZIESCHANG, BLS, Washington D.C., USA

19:00 Dinner at "La Cuisine des Champs"

Saturday October 26 — Morning sessions

Chair : Bernard THIRY

- 9:00 Ole OLESEN and Niels Christian PETERSEN, Odense University
"Collinearity in Data Envelopment Analysis: An Extended Facet Approach"
- 9:45 Bill SEAVER, Western Illinois University and
Kostantinos TRIANTIS, VPI-Falls Church, Virginia
"The Effect of Outliers and Leverage Points on Efficiency Measurement
and Evaluation: An Analysis Using Robust Methods And Fuzzy Clustering"
- 10:30 Coffee Break
- 11:00 Peter BOGETOFT, DASY, Copenhagen Business School
"Strategic Responses to DEA-Control — A Game-Theoretical Analysis"
Discussant: Liang ZOU, Maastricht University, Netherlands
- 12:00 Lunch at "La Sablonnière"

Saturday October 26 — Afternoon Sessions

Chair : C.A. Knox LOVELL

- 13:45 Tom GULLEDGE, George Mason University and
N. Keith WOMER, University of Mississippi
"Learning Augmented Production Planning Models"
Discussant: Maurice MARCHAND, CORE
- 14:30 Marc IVALDI, GREMACQ, Toulouse,
Isabelle PERRIGNE and Michel SIMIONI, INRA, Toulouse
"A Latent Trait Model to Measure Productive Efficiency:
Some New Evidence for the French Cereal Sector"
- 15:00 Coffee Break
- 15:30 Lennart HJALMARSSON and Ann WEIDERPASS, University of Gothenburg
"Productivity Change in Swedish Electricity Distribution"
- 16:00 Bernard DELHAUSSE, Fabienne FECHER, Sergio PERELMAN, and
Pierre PESTIEAU, Université de Liège
"Measuring Productive Performance in the Insurance Industry :
The Case of French and Belgian Markets"
- 16:30 "Closing remarks" Henry TULKENS
- 16:35 Cocktails in CORE lounge

SECOND EUROPEAN WORKSHOP ON EFFICIENCY AND PRODUCTIVITY MEASUREMENT
Methodology and Applications

Louvain-la-Neuve, October 25-26, 1991.

Abstracts of papers

Peter BOGETOFT, DASY (Copenhagen Business School)

"Strategic Responses to DEA-Control — A Game-Theoretical Analysis"

We examine how announced or otherwise foreseen Data Envelopment Analysis (DEA) evaluations may affect the behavior of Decision Making Units (DMUs). We show that the use of "best performance" standards may impose excessive risks on the DMUs and that it may therefore not be a cost minimal way to deter shirking. However, we also identify some environments where the use of such standards may indeed be appropriate. Furthermore, we investigate how the DMUs may strategically utilize the multiple dimensional character of DEA evaluations. A DMU may for example specialize, hereby protecting against control by making it more difficult for the evaluator to find comparable units, or it may imitate other DMUs, hereby protecting against the arbitrariness of evaluations. We show how the relative attractiveness of such responses depends on the productive uncertainties in our model.

Julien van den BROECK (State University Centre, Antwerp), Jacek OSIEWALSKI (Academy of Economics, Krakow) and Mark F.J. STEEL (Tilburg University, Tilburg)

"Stochastic Frontier Models : A Bayesian Perspective"

A Bayesian approach to estimation, prediction and model comparison in composed error production models is presented. A broad range of distributions on the inefficiency term define the contending models, which can either be treated separately or pooled.

Posterior results are derived for the individual inefficiencies as well as for the parameters, and the differences with the usual sampling-theory approach are highlighted.

The required numerical integrations are handled by Monte-Carlo methods with Importance Sampling, and an empirical example illustrates the procedures.

Bernard DELHAUSSE, Fabienne FECHER, Sergio PERELMAN & Pierre PESTIEAU (Université de Liège)

"Measuring Productive Performance in the Insurance Industry : the Case of French and Belgian Markets"

The purpose of this paper is to provide for both life and non life insurance an assessment of the relative productive performance of Belgian and French companies.

We use both a parametric and a non parametric approach to construct a frontier to be used as a yardstick of productive efficiency. Our data basis covers near 600 life and non life companies for the period 1982-89. The main findings show a high correlation between parametric and non parametric results, a wide dispersion in the rates of inefficiency across companies and a significant effect of scale, institutional form, reinsurance and claims to premiums ratios on the average level of efficiency.

Rolf FÄRE (Southern Illinois University at Carbondale)

"The Malmquist Productivity Index and the Circular Test"

Caves, Christensen and Diewert (1982) introduced Malmquist productivity indexes as ratios of distance functions. They named it after S. Malmquist who in his 1953 paper used input distance functions to define input quantity indexes. They proved that the geometric mean of two such productivity indexes becomes a ratio of Törnquist indexes (i.e., a Törnquist productivity index) provided that the distance functions are of translog form with identical second-order coefficients and that firms are optimizers. Later Färe and Grosskopf (1990) showed that the geometric mean of two Malmquist indexes may also be expressed as the ratio of two Fisher ideal indexes (i.e., as a Fisher productivity index). They do not impose any functional structure on the distance functions, but they do assume optimizing behavior. Finally, Diewert (1989), again imposing functional structure and optimization, showed that a Fisher productivity index could be obtained from a single Malmquist productivity index.

Färe, Grosskopf, Lindgren and Roos (1989) in analyzing panel data of Swedish hospitals defined the Malmquist productivity index as the geometric mean of Malmquist indexes of adjacent periods, see below. Here we adopt their definition.

Försund (1990) points out that, in general, the Malmquist productivity index adopted by Färe, Grosskopf, Lindgren and Roos does not satisfy the circular test. Recall that if p^{01} , p^{12} and p^{02} are three index numbers, where p^{ij} expresses the (price) level at j in terms of i , then the circular test requires that $p^{01} \cdot p^{12} = p^{02}$. Although many indexes do not meet the circular test, see e.g. Eichhorn (1978) or Frisch (1936), Försund (1990, p.13) states: "One preferable property with an index over a longer period of time is that it is possible to chain it, i.e., that the index obeys the "circular relation" of Frisch (1936)."

In this paper we provide necessary and sufficient conditions on the output distance functions for the Malmquist index to satisfy the circular test. The conditions found on the distance functions are equivalent to Hicks output neutrality, meaning that the output set is neutrally (or homothetically) influenced by technological change.

Finn FØRSUND (University of Oslo)

"The Malmquist Productivity Index"

Key concepts when studying production over time are productivity, efficiency and technical change. Empirical studies show that a generic feature of production units at the micro level in the same business is that efficiency varies across units. A natural reference for technology is then best practice or the frontier production function. Change in productivity is the net effect of changes in efficiency and shift in the frontier production function.

When calculating total factor productivity change using the basic definition of an index of outputs on an index of inputs the question is how to construct the weights. Instead of using price information necessary to calculate cost-and income shares as weights, the idea of the Malmquist index is to reduce the multi-dimensionality by comparing productivity keeping the observed proportions between outputs and inputs. Studying a unit at two different points in time there must be a common reference of technology, and uni-dimensionality is obtained by establishing distances to the common technology and measuring productivity change by the ratio of such distances.

In a more general setting of several time periods one has to face the choice of base of reference. One preferable property with an index over a longer period of time is that it is possible to chain it. Total productivity change over a certain period can then be broken down on subperiods in a consistent way. The Malmquist index with fixed base technology does chain. When decomposing into an efficiency part, the catching-up term, and a technical change term, the frontier function shift, the latter term has to be defined in a special way to permit chaining.

René GOUDRIAAN (Erasmus University, Rotterdam) and Hans DE GROOT (Institute for Research on Public Expenditure, The Hague)

"Scale and Efficiency in Higher Education : a Comparison of Parametric and Non-parametric Approaches"

For a long time research on the economics of higher education has recognized the possible effects of the scale of operations for the efficiency of higher education. The collection of empirical evidence has been slow, however, in particular for multi-product organizations such as research universities. In fact, recent research seems to suggest that the most productive scale of universities is heavily dependent on the output mix. Moreover, the scant empirical evidence is almost exclusively based on econometric estimation of parametric cost functions.

In this paper we try to shed more light on the most productive scale of American research universities, using a unique sample of data on costs, quality and outputs for 49 private and 98 public institutions. In order to distinguish between cost variation due to scale and cost variation attributable to inefficiency, we utilize the concept of the cost frontier. Two different techniques for computing the cost frontier are employed. One approach involves the econometric estimation of a parametric frontier, while the

second consists of a series linear programs that calculate a nonparametric frontier. Both techniques have different strengths and weaknesses, but have been compared infrequently. It is useful, therefore, to study the sensitivity of the results when both techniques are applied to one and the same data set.

Shawna GROSSKOPF (Southern Illinois University, Carbondale), Kathy HAYES (Southern Methodist University, Austin, Texas), L. TAYLOR (Federal Reserve Bank of Dallas) and W. WEBER (Southcast Missouri State University, Cape Girardeau)

"Teacher Salaries and Productivity"

The purpose of this paper is to determine whether teacher and other school personnel salaries are consistent with an efficient allocation of resources. We do so by comparing observed salaries to shadow values which reflect productivity. These shadow values are calculated using techniques recently developed by Färe and Grosskopf [1990]. This entails estimating an input distance function, which is a multiple output generalization of a production function. This distance function is dual to the cost function, which allows us to employ a dual Shephard's lemma to derive shadow prices for school personnel. These may then be compared to observed prices to determine if the allocation of resources is efficient, i.e., reflects relative marginal productivities. These shadow prices can be estimated at the school level and can be used to determine if schools are hiring the optimal mix of teachers and administrators, for example. We can also provide evidence as to whether teachers are in a monopsony market, i.e., we can determine whether teachers are paid less than their value marginal products. We apply our techniques to a sample of Texas schools. One advantage of the distance function approach used here is that it readily allows for the possibility of multiple outputs. Our data allows us to identify fourteen educational outputs which are constructed to reflect value added by the schools.

Thomas R. GULLEDGE (George Mason University, VA) and Norman Keith WOMER (University of Mississippi)

"Learning Augmented Production Planning Models"

This paper is in two parts. The first part surveys our work in incorporating learning into microeconomic production models. Our approach applies continuous dynamic optimization to parametric specifications in modeling cost for made-to-order systems. The resulting cost functions, which may be thought of as forms of the learning curve, may be used to model variable cost within decision support systems for repricing procurement programs.

The second part of the paper extends our earlier ideas and estimates the learning augmented cost function as a cost frontier. We show with an example from an aircraft production program how resource efficiency computations can be used to test a hypothesis related to procurement program stabilization.

The entire presentation will be tutorial in nature with emphasis on basic concepts, including a survey on the early economics literature that integrates learning into cost and production functions. We also show how our work relates to recent studies on the origins of the learning curve.

Peter HALL (Australian University), Wolfgang HÄRDLE (CORE, Université Catholique de Louvain) and Léopold SIMAR (CORE, Université Catholique de Louvain)

"Iterated Bootstrap with Applications to Frontier Models"

The iterated bootstrap may be used to estimate errors which arise from a single pass of the bootstrap and thereby to correct for them. Here the iteration is employed to correct for coverage probability of confidence intervals obtained by a percentile method in the context of production frontier estimation with panel data. The parameter of interest is the maximum of the intercepts in a fixed firm effect model. The bootstrap distribution estimators are consistent if and only if there are no ties for this maximum. In the regular case (no ties), poor distribution estimators can result when the second largest intercept is close to the maximum. The iterated bootstrap is thus suggested to improve the accuracy of the obtained distributions. The result is illustrated in the analysis of labor efficiency of railways companies.

Lennart HJALMARSSON (University of Göteborg) and Ann WEIDERPASS (University of Göteborg)

"Productivity Change in Swedish Electricity Distribution"

This paper examines productivity growth in electricity retail distribution in Sweden in a multiple output - multiple input framework. The approach used is nonparametric Data Envelopment Analysis (DEA). Productivity is measured by means of the Malmquist index. Productivity comparisons are made between different types of ownership and between different service areas.

The study indicates a high rate of productivity growth when output is measured by the amount of electricity supplied and a low rate of productivity growth when output is measured by the number of customers served.

A high rate of productivity growth, due to economies of density, is also found when all four outputs are included in the model.

The results show no significant differences in productivity growth between different types of ownership or economic organization.

Marc IVALDI (GREMACQ, Toulouse), Isabelle PERRIGNE (INRA, Toulouse) and Michel SIMIONI (INRA, Toulouse)

"A Latent Trait Model to Measure Productive Efficiency ; Some New Evidences for French Cereal Sector"

This paper deals with the issue of estimating production frontier and measuring technical efficiency from a panel data of cereal producers in France. We use a parametric approach to productive efficiency based on the specification of a stochastic frontier of production. The use of panel data enables us to recover the individual levels of efficiency without making strong hypotheses on their distribution. We incorporate a quadratic function of time for the efficiency term where coefficients vary over individuals. Moreover, we allow for the existence of correlations between inputs and efficiency terms.

Our approach is based on a mean-and-covariance structure analysis which provides a more general method than usual instrumental variables methods for our problem. In addition, the knowledge of the means and covariances of individual effects obtained at the estimation stage combined with the residuals of the production frontier model can be used to recover individual estimates of efficiency levels.

We apply this approach to a panel of french cereal producers from 1982 to 1986. Our empirical results show that efficiency levels increase over time. Second, there is a negative correlation between individual levels of productivity and utilization of materials.

Knox LOVELL (University of North-Carolina)

"Resources and Functionings : a New View of Inequality in Australia"

We use an input distance function to construct an approximate standard of living index, which we then use to measure inequality in the distribution of individual resources. We use an output distance function to construct an approximate quality of life index, which we then use to measure inequality in the distribution of individual functionings. We also use an output distance function to measure the relative abilities of individuals to convert their resources into functionings, in an effort to explain the relationship between the standard of living and the quality of life. The empirical analysis is carried out on a 1987 sample of 1069 individuals, using data culled from the Australian Standard of Living Study.

Ole OLESEN (Odense Universitet, Danmark) and Niels PETERSEN (Odense Universitet, Danmark)

"Collinearity in Data Envelopment Analysis : an Extended Facet Approach"

Data Envelopment Analysis employs mathematical programming to measure the relative efficiency of decision making units (DMU's). The mathematical programming approach implies that DEA provides well defined efficiency indices with the number of input and output dimensions arbitrarily large, i.e. the level of disaggregation has no theoretical bound. In the present paper it is argued that disaggregation in DEA may cause collinearity as in the family of parametric models. Collinearity implies a fixed frontier technology in the sense that some inputs/outputs must be used/produced in fixed proportions and constitutes as such a possible misspecification of the production correspondence.

A test for local collinearity in DEA is suggested. The existence of full dimensional faces is the keypoint in the test. A two stage estimation of a lower and an upper bound on the efficiency score of each DMU is presented. The two stage approach is necessary when a fixed frontier technology is unacceptable.

Bill SEAVER (Western Illinois University) and Kostantinos TRIANTIS (Virginia Polytechnic Institute at Falls Church, Virginia)

"The Effect of Outliers and Leverage Points on Efficiency Measurement and Evaluation : an Analysis Using Robust Methods and Fuzzy Clustering."

The objective of this presentation is to discuss the effect of some data problems on efficiency measurement and evaluation. Specifically, the existence of outliers and leverage points impacts corrected ordinary least squares (COLS) approach. Of special interest is to isolate the robustness of the parameter coefficients in light of the existence of outliers and leverage points when using the COLS approach and the sensitivity of the computed technical efficiency measures when employing a LP approach. The weighted least squares and minimum volume ellipsoid procedures are used to address the issue of the robustness of the LS parameter estimates.

Additionally, comparing analytical approaches is crucial when important policy decisions of corporations or government agencies may be influenced by results that depend on the methodologies certain discipline use. Inconsistency of efficiency rankings when using the COLS and LP approaches can lead to confusion as far as crucial to explore the impact of outliers and leverage points on efficiency rankings. Also, a modified hat matrix H^* and a fuzzy k-means clustering approach permit observations to be allocated to clusters in a fuzzy way or allow construction of a membership function in the 0 to 1 range. As the degree of fuzziness increases, a sensitivity analysis on individual observation and their belonging to some phase of the efficiency spectrum can be evaluated. At the same time, this fuzzy approach brings some clarity to the inconsistencies that arise when using the LP and COLS approaches.

Finally, the input specification problem will be addressed when one of the input variables has a measurement problem. The data set that is being used for this research pertains to linerboard manufacturing facilities. For this data set, the capital

variable has both fixed and variable cost components in its definition. The variable cost component is highly correlated with output thus impacting the statistical bias of the COLS parameter estimates. The relative performance with respect to the robustness of parameter estimates, the discriminatory power in relation to efficiency measurement and the consistency of efficiency rankings of alternative production frontier specifications is presented.

Henry TULKENS (Core, Université Catholique de Louvain) and Philippe VANDEN EECKAUT (CORE, Université Catholique de Louvain)

"Non Parametric Indexes of Efficiency, Progress and Regress"

This paper develops some methodology for efficiency measurement from time series and panel data. When the underlying technology is assumed to be of the FDH type, the notion of "domination" between pairs of observations plays a central role. From a detailed analysis of the various forms under which data can dominate each other over time, it is first recalled how each observation can be characterized in efficiency terms vis a vis three different kinds of frontiers : (i) an "intertemporal" one; (ii) a "contemporaneous" one; and (iii) a "sequential" one (to be contrasted with window analysis in DEA).

Then, from alternative ways of considering sequential domination, two complementary measures of technical change can be identified. While the first one rests on the notion of local upward shifts in the production frontier, the second one identifies (in)efficiency, progress or regress by referring to some benchmark which is not a frontier anymore. With panel data, these characterisations can be made at both a unit specific level and at a global level. The methodology applies to both multiple outputs and multiple inputs, irrespective of whether the panel is balanced or not.

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