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Suitability of forest enterprises as decision making units in comparative efficiency analysis

Walter Sekot

Data Envelopment Analysis (DEA)

– *an overview*

- DEA is a non-parametric approach based on linear programming to measure the efficiency of multiple Decision Making Units (DMUs).
- Any managed input/output-system may be considered as a DMU.
- DEA assesses **relative efficiency** : a DMU is considered as efficient when the peer units documenting best practice provide no indication that any of the inputs or outputs could be improved without worsening at least one of the others.
- DEA represents a powerful analytical toolbox comprising a range of alternative model specifications and providing a variety of efficiency measures.



Alternative model specifications & efficiency measures in DEA

- Input-oriented / output-oriented / non-oriented model
- Variable (increasing or decreasing) returns to scale / constant returns to scale
- Unrestricted weights / boundaries and other weight restrictions
- Technical efficiency / allocative efficiency / cost efficiency
- Radial (equiproportional) measure / additive measure
- maxAverage (Färe-Lovell) measure / minAverage measure

General benefits of DEA



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- + There is no need to explicitly specify a mathematical form for the production function.
- + DEA is capable of simultaneously handling multiple inputs and outputs.
- + DMUs are directly compared against a peer or combination of peers so that the sources of inefficiency can be analyzed and quantified for each evaluated unit.
- + Inputs and outputs may have totally different units without requiring an a priori tradeoff between them.

General challenges for model specification



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- Identification and delimitation of DMUs according to the goal of the investigation
- Performing the trade-off between the number of DMUs available for analysis and the level of similarity and comparability
- Creating a comprehensive set of inputs and outputs
- Identifying an appropriate level of aggregation for representing the individual inputs and outputs (e.g. timber as a whole or individual species and assortments)
- Meeting the threshold-level for the number of DMUs
(*rule of thumb: number of DMUs = 3 (10) x number of variables*)
- Properly taking into account non-discretionary (= exogenously fixed) inputs and outputs



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Application of DEA in forestry

few studies but promising prospects

„DEA represents a promising alternative to performance measurements in forestry. There are many areas in which a DEA-based analysis will enhance our understanding of some important technical and managerial issues in forest industries and aid forest managers in decision making.“

(Sowlati 2005, p. 56)

Forestry specific challenges for model specification



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- How to account for intentionally provided non-market outputs, forest services and externalities?
- How to properly account for changes in the forest property due to over- or undercutting in terms of volume, value or structure?
- How to account for the specific outputs associated with inputs related to the cost centers 'silviculture', 'administration' and 'forest roads & buildings'?
- How to deal with the multitude of non-discretionary variables like terrain, site productivity or weather conditions?
- Which categories of forest enterprises are to be considered as being comparable, which not? (e.g. types of ownership)

Test application utilizing the accountancy data of bigger forest enterprises



- Panel of 76 enterprises > 500 ha
- Calibrating by relating all values to the unit of area (1 hectare)
- Accounting for over- or undercutting by transforming the data to the level of the allowable cut
- Smoothing by calculating yearly averages over a period of 5 years
- 4 Input variables:
 - *Working hours*
 - *Number of employees*
 - *Cost of contractor's work*
 - *Other costs*
- 3 Output variables:
 - *Volume of industrial roundwood harvested*
 - *Volume of pulpwood and fuelwood harvested*
 - *Non-timber revenues*

Average levels of efficiency

(radial, equi-proportional measure)



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Technical efficiency:

Model	Returns to scale	Efficiency
Input-oriented	Variable	91.8 %
Input-oriented	Constant	89.3 %
Non-oriented	Variable	95.2 %
Non-oriented	Constant	93.9 %

Scale efficiency of the input-oriented model: 97.2 %

Scale efficiency of the non-oriented model: 98.6 %

Potential improvements (averages) in terms of technical efficiency

(values in %)



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Model	I1: hours	I2: empl.	I3: contr.	I4: other	O1: round- wood	O2: pulp- wood	O3: non- timber
Input-oriented	-11.6	-9.9	-9.1	-9.2	0.0	0.0	0.0
Non-oriented	-8.9	-6.9	-6.0	-6.1	4.8	7.3	39.9

Results for an individual DMU

*(cross-sectional time-series with 380 DMUs = 76 enterprises * 5 years;
variable returns to scale; input-oriented, radial models)*



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Model & type of efficiency	Value	Rank	Benchmark units
Technical efficiency	79.9 %	240	55 (0.08) / 250 (0.18) / 306 (0.74)
Cost-efficiency at average factor prices	67.8 %	258	261 (0.70) / 306 (0.18) / 347 (0.12)
Allocative efficiency	85.0 %	257	
Cost-efficiency at effective factor costs	64.9 %	286	86 (0.39) / 205 (0.43) / 306 (0.18)

Target values for an individual DMU

*(cross-sectional time-series with 380 DMUs = 76 enterprises * 5 years;
variable returns to scale; non-oriented models of technical efficiency;
target values in %)*



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Measure	I1: hours	I2: empl.	I3: contr.	I4: other	O1: round- wood	O2: pulp- wood	O3: non- timber
Radial	-19.82	-14.92	-13.36	-13.36	13.36	67.10	94.43
Max Average	0.00	-18.23	0.00	-14.65	0.00	69.33	303.09
Min Average	0.00	0.00	-26.07	0.00	0.00	0.00	0.00

Test application utilizing the accountancy data of farm forest enterprises



- Total of 137 enterprises < 200 ha; years 1999 - 2007
- Focus on harvesting by own means (\Rightarrow excluding contractors' work and selling on the stump)
- 3 variants as regards the area:
disregarded / as a non-discretionary input / transformation into per ha values
- Yearly averages over the individual period of participation (1 – 9 years) \Rightarrow varying effect of smoothing in favor of maximizing the number of DMUs as compared to a panel
- 5 Input variables (pertaining to the cost center 'harvesting'):
 - *Family labor working hours*
 - *Working hours of the tractor*
 - *Working hours of farm staff*
 - *Km of own car*
 - *Monetary outlay and depreciation related to other inputs (deflated values)*
- 2 Output variables:
 - *Volume of harvest by own means*
 - *Volume of timber transported out of the forest by own means*



Technical efficiencies *(variable returns to scale; radial measures; share of efficient units given in brackets)*



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Model	total	alpine	others
Input-oriented; area disregarded	68.2 (21%)	72.1 (23%)	58.5 (15%)
Input-oriented; area as non-discretionary	69.6 (23%)	72.6 (24%)	62.0 (21%)
Input-oriented; values per ha	65.6 (15%)	68.7 (14%)	57.9 (15%)
Non-oriented; area disregarded	80.5 (21%)	83.7 (23%)	72.2 (15%)
Non-oriented; area as non-discretionary	94.6 (23%)	96.1 (24%)	90.6 (21%)
Non-oriented; values per ha	76.5 (15%)	78.5 (14%)	71.7 (15%)

Efficiency analysis at enterprise level

Lessons of tentative DEA-exercises based on data of forest accountancy networks

- ☺ DEA enriches the analytical toolbox as it refers to entire input/output-systems and allows for a differentiated analysis at physical and monetary levels
- ☹ Highly aggregated inputs and outputs – which may be a pre-requisite for discriminant models and significant results – are not likely to correspond to the level of operation, where improvements are to be induced
- ☹ The models hardly comprise all of the relevant elements affecting the level of relative efficiency so that unrealistic target values may be derived
- DEA shares the general shortcomings of efficiency analysis and interfirm comparisons in forestry

Conclusions:

DEA-exercises may further the general understanding of forest enterprises as complex productive systems

However, the industry-specific characteristics imply a limited suitability of forest enterprises as decision making units

Practical applications aiming at the rationalization of operations should therefore focus on technical sub-systems



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**Thank you very much
for your attention and interest!**

All questions welcome