The sustainability of a community nurses programme in mountain areas: a Directional Distance Function approach

Greta Falavigna[+], Roberto Ippoliti*[✠], Floriana Montani[✠] & Silvia Rizzi[✠]

[+]CNR-IRCrES (Moncalieri), *University of Turin & [✠]Piedmont Region

XXXIX° Annual Scientific Conference of AISRE
17-19 September 2018, Bolzano

1. Introduction
   - Research issues
   - Tehoretical motivations of study
2. Methodology
   - Methodological background
   - Notation and axioms: DDF
   - Bootstrapped DDF scores
   - Model definition
3. Data and Results
   - Data
   - Results
4. Simulation of interventions
   - Economic impact
5. Conclusion and discussion

- This study starts from the CoNSENSo project, funded by the European Union with the INTERREG Alpine Space Programme.
- The CoNSENSo is aimed at developing an innovative care model based on Community Nurses (CNs) to support active ageing in mountain areas

Main goals

- To suggest a specific score able to identify all those municipalities that are inefficient in supporting the aging process
- According to the estimated scores, the policy maker can use more rationally the available resources, implementing the innovative treatments where it is extremely necessary

Applied methodology and target sample

- Bootstrapped Directional Distance Function Approach
- *Sample*: Municipalities of mountain areas of Piedmont and 65 years older population

- Limits and difficulties in the utilization of healthcare services among the rural population, as well as the opportunities for an active and healthy ageing
- Ippoliti et al. (2018a), considering the specific characteristics of this local health care market, which is shaped around Local Health Authorities:
  - LHAs support services by Family Doctors, who are responsible for the comprehensive healthcare of elderly patients, provided through outpatient clinic visits and then, based on their results, drug and/or specialist prescriptions
  - These LHAs supply all the necessary treatments and services, which are made in house or bought on the market
- Ippoliti et al. (2018a) estimate that the expected cost of implementing the proposed innovative health care service to the whole mountain areas in Piedmont for 3 years would be above 24 million Euro
- The Regional Health Care System might identify municipalities where the interventions of these CNs are clearly necessary to support the active and healthy aging process

Short references on non-parametric models

- The Directional Distance Function (DDF) is a specification of the standard Data Envelopment Analysis model (DEA)
- The DEA model is a non-parametric technique allowing to build a frontier on which the efficient observations (i.e., Decision Making Units, DMUs) are placed on. Bigger the distance from the frontier, bigger the inefficiency.
- However, DEA model have been built thinking of two main approaches:
  - *Input Orientation*: benchmark DMUs are those able to produce the same output, minimizing inputs
  - *Output Orientation*: benchmark DMUs are those able to maximize output, taking constant the inputs

The Directional Distance Function: whst's new?

- The Directional Distance Function (DDF) leads to a specific weakness of the DEA standard model
- Indeed, in some specific industries, a strong necessity to consider different types of outputs was perceived
- So, seminal work on DDF can be found in environmental field, where firms produce not only goods/services but also pollution
- The hystory of DDF starts from this consideration: in reality, often the DMUs can produce:
  - *Good output*: goods/services to sell, i.e., desirable production
  - *Bad output*: non saleable production, so called "undesirable output"
- The proposed DDF model is then able to maximize "desirable outputs"and minimize "undesirable ones", taking inputs constant
- Even if this technique was born in environmeal field, many applications on other contexts where the production set is heterogeneus can be found (e.g., health care market; energy market; eco-efficiency; judiciary systes)

Directional Distance Function

Formal definition:

$$\vec{D}_0^W(x, y, b; g_y, g_b) = \max\{\beta : (y, b) + (\beta g_y, \beta g_b) \in P(x)\}$$

where $g = (g_y, g_b)$ is the directional vector and $g_y \in R_+^M$, $g_b \in R_+^J$.

An asymmetrical treatment of goods and bad outputs is needed:

- β represents the maximal feasible expansion of good and bad outputs along the pre-assigned direction g vector.
- An appropriate direction should be choose in order to guarantee expansion of good outputs and contraction of bad outputs.
- A firm is efficient if β (TE scores) $= 0$
- Authors applied the specific form of Shephard's output distance function, so β (TE) scores vary between 0 and 1. Growing the coefficient, bigger the inefficiency
- Constant Returns to Scale (CRS) have been applied

Standard axioms satisfied by technology:

1. Inactivity is always possible $0 \in P(x), \forall x \in R_+^N$
2. $P(x)$ is compact (finite x gives finite (y, b))
3. Inputs are freely disposable $P(x) \subseteq P(x')$ if $x' \geq x$

Bad outputs are byproduct results and it is costly to reduce them:

4. Weak disposability assumption on outputs (y, b):

$$(y, b) \in P(x) \text{ and } 0 \leq \alpha \leq 1 \Longrightarrow (\alpha y, \alpha b) \in P(x)$$

5. Null jointness: $(y, b) \in P(x)$ and $b = 0 \Longrightarrow y = 0$

Free disposability is valid only if one can costlessly dispose of undesirable outputs:

$$(y, b) \in P(x) \text{ and } (y', b') \leq (y, b) \Longrightarrow (y', b') \in P(x)$$

Free disposability remains valid for good outputs:

$$(y, b) \in P(x) \text{ and } y' \leq y \Longrightarrow (y', b) \in P(x)$$

Biased efficency score $\rightarrow \hat{\beta}^{*}_{bias}(x,y) = BTE$

- Bootstrap procedure is a mathematical methodology that allows to replicate N random sub-samples, starting from the initial dataset (in this work N was set to 100 replications)
- The main result of bootstrapping is a correction of DDF estimates with a bias term computed following suggestions of Simar and Wilson for non parametric approach (1998, 2007)

Considering only one firm (i.e., DMU), the bias for the DDF score is:

$$bias = \frac{\sum_{n=1}^{N} \hat{\beta}^{n}(x,y)}{N} - \hat{\beta}^{*}(x,y) = \bar{\beta}(x,y) - \hat{\beta}^{*}(x,y)$$

... and the biased efficiency estimate is:

$$\hat{\beta}^{*}_{bias}(x,y) = BTE = \hat{\beta}^{*}(x,y) - bias = 2 \cdot \hat{\beta}^{*}(x,y) - \bar{\beta}(x,y)$$

[*Notation*: **TE = Technical Efficiency scores; BTE = Biased Technical Efficiency scores**]

What represent TE/BTE scores in Piedmont mountain area?

The meaning of Technical Efficiency

- Efficiency represents the ability of municipalities in supporting an active and healthy ageing of elderly who are resident in mountain areas
- How computing TE/BTE scores? Maximizing the number of resident elderly (i.e., good output) and, at the same time, minimizing the adverse health events (i.e., bad outcome), considering the used financial resources (i.e., inputs)
- Authors propose 3 inputs, 6 good and 1 bad outputs
- Considering the municipalities located in Piedmont (mountain area) and focusing on 2013

Two models

- *Model A*: municipalities are considered common DMU
- *Model B*: altitude stratification of municipalities. Different frontiers have been estimated according to 4 altimetric classes (altitude increases from 1 to 4)

Inputs, Good and Bad Outputs

Inputs [*Source*: Istat]

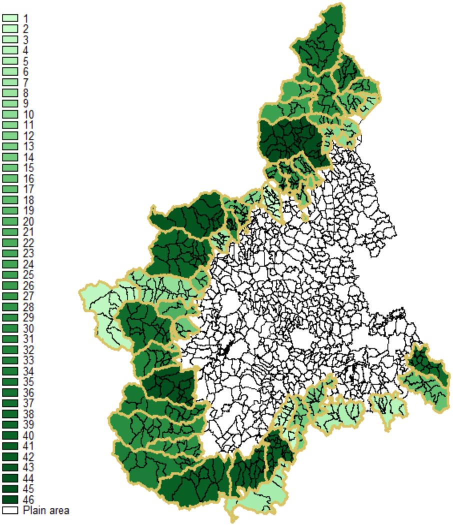
Financial resources to support the active and healthy aging with social interventions, disaggregated according to the contributor:

- Municipalities (i.e., 1st input)
- Regional local health care system (i.e., 2nd input)
- Elderly (i.e., 3rd input)

Good and Bad Outputs [*Source*: Istat and Piedmont Region]

- *Good output* →Number of male and female in 3 age categories:
  - 65-74 years old (i.e., 1st and 2nd good output)
  - 75-84 years old (i.e., 3rd and 4th good output)
  - Those older than 85 years (i.e., 5th and 6th good output).
- *Bad output* →Number of hip francture that have occurred in the selected year on these elderly population

Regional Health Care System in Piedmont



- 13 Local Health Authorities (LHAs), with a variable number of districts
- LHAs are responsible for the whole elderly population, both in mountain and plain areas, equal to 191,977 and 899,434 individuals respectively (Ippoliti et al., 2018a)
- There are 1,208 municipalities in Piedmont with 524 aggregated in 46 mountain area (i.e., *comunità montane*) while 684 in plain area (i.e., Po valley)
- The presence of a bad output (i.e., hip fracture) has been selected as second admission criteria for our analysis
- Considering these 524 municipalities located in mountain area, we observed at least 1 hip fracture in 457 observations. This is the sample of our analysis (i.e., DMUs)

Descriptive statistics of input-output space and BTE/TE scores

Type	Variable	Obs	Mean	Std. Dev.	Min	Max
Input	Municipalities	457	161,509.40	363,529.10	340	4,568,474.00
	Health Care System	457	49,121.52	167,213.00	0	2,268,698.00
	Elderly	457	60,220.46	289,902.50	0	2,905,473.00
Good output	Male (65-74 years old)	457	95.781	134.62	3	1053
	Female (65-74 years old)	457	100.42	150.543	1	1264
	Male (75-84 years old)	457	62.47	87.661	1	741
	Female (75-84 years old)	457	83.864	124.543	0	987
	Male (older than 85 years)	457	17.488	23.42	0	183
	Female (older than 85 years)	457	43.462	63.7	0	471
Bad output	Hip fractures	457	3.406	4.926	0.333	36.333
Efficiency scores	TE scores (Model A)	457	0.286	0.16	0	0.934
	BTE scores (Model A)	457	0.329	0.175	0	0.966
	TE scores (Model B)	457	0.177	0.15	0	0.827
	BTE scores (Model B)	457	0.298	0.258	0	1.654

Descriptive statistics of TE/BTE scores according to classes of altitude (Model B)

Variables	Statistics	Class 1	Class 2	Class 3	Class 4
TE scores	Mean	0,111	0,186	0,193	0,153
	Std. Dev.	0,123	0,128	0,163	0,205
	Min	0,000	0,000	0,000	0,000
	Max	0,352	0,647	0,827	0,725
BTE scores	Mean	0,215	0,287	0,336	0,312
	Std. Dev.	0,215	0,207	0,281	0,391
	Min	0,000	0,000	0,000	0,000
	Max	0,657	1,080	1,654	1,451

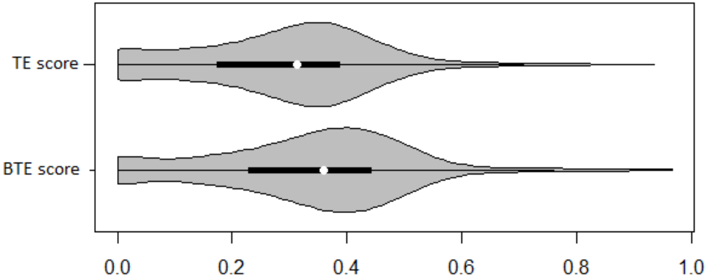
Altimetric classes (meters) and Sample size

- *Class 1*: alt <= 300
- *Class 2*: 300 < alt <= 600
- *Class 3*: 600 < alt <= 900
- *Class 4*: 900 < alt <= 1200

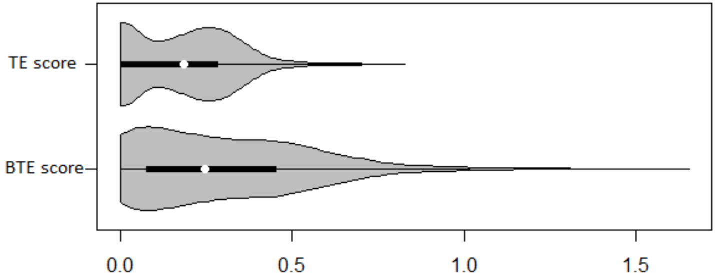
- *Sample size Class 1*: 48
- *Sample size Class 2*: 212
- *Sample size Class 3*: 154
- *Sample size Class 4*: 43

Model A: Violin plots of TE/BTE scores without altitude stratification

- The violin plot is a graphical representation combining the standard box plot and the kernel density plot
- It starts with a box plot and then a rotated kernel density function is represented to each side of the box plot (i.e., the gray area)



Model B: Violin plots of TE/BTE scores with altitude stratification and $t - test$

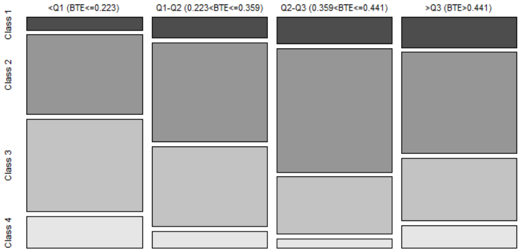


$t - test$ on BTE means

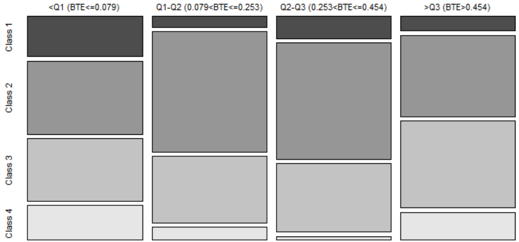
- $H_0 : BTE_{ModA} - BTE_{ModB} = 0$
- We can reject the null hypothesis with a significant level of 5%
- Stratifying for altitude can change results in efficiency estimation of municipalities

Mosaic plots of BTE scores - Model A and Model B

Model A



Model B



$t - test$ on BTE means

- $H_0 : BTE_{ModA}ClassX - BTE_{ModB}ClassX = 0$ where $X = 1, \ldots, 4$
- *Classes 1 and 2*: we can reject the null hypothesis. There is a statistical significant difference
- *Class 3*: we can observe a weaker statistical rejection (i.e., we can reject H0 with a significant level of 24%)
- *Class 4*: results suggest the acceptance of H_0. There is no statistical significant difference
- *Samples size*. Class 1: 48 m.; Class 2: 212 m.; Class 3: 154 m.; Class 4: 43 m.
- Each *rectangle* contains 114 obs, except the first collecting 115 m.

Expected economic impact

- Considering the elderly population in 2015 (i.e., 191,977 inhabitants) and the proposal of extending the innovative model to all mountain areas in the Piedmont Region (i.e., 525 municipalities), Ippoliti et al. (2018a) estimated that the expected cost for 3 years would be above 24 million €
- According to the proposed results:
  - Human costs are the most significant (7,305,826.40€per year)
  - Transportation costs are equal to 524,996.48€for the first year, since one visit only is envisaged (i.e., mapping of the elderly population through a first round of visits)
  - Transportation costs amount to 725,096.16€per year for the following two years, since two follow-up visits are planned

Estimate of cost of treating a selcted number of municipalities

Authors estimated the cost to treat the municipalities with an estimated BTE score higher than 0.454, which is exactly the last inter-quartile subgroup. These municipalities represent those DMUs with the highest inefficiency.

Detailed costs of the innovative care model for each LHA covering mountain areas

- Treated municipalities = 114
- The expected cost for 3 years would be above 5 million Euro
- Selecting the DMUs according to the proposed score, the policy maker would reduce the economic burden of this intervention of 76%

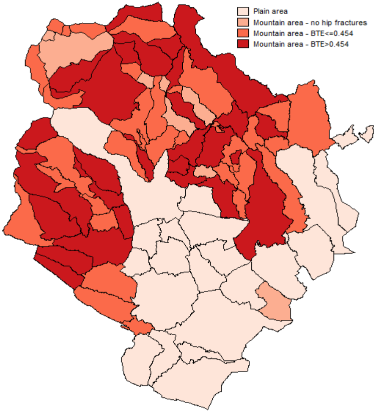
LHAs	Human cost (€)	Transport cost (€)	Total cost (€)
AL	38,939	5,869	44,808
AT	27,704	1,720	29,424
BI	1,574,040	111,093	1,685,133
CN1	474,964	49,564	524,528
CN2	13,710	2,342	16,051
TO3	699,253	128,905	828,158
TO4	412,863	44,092	456,955
VC	644,190	27,356	671,546
VCO	1,372,095	97,194	1,469,289
Total	**5,257,757**	**468,135**	**5,725,892**

Biella and Verbano-Cusio-Ossola

Biella

22 municipalities, 14,733 elderly

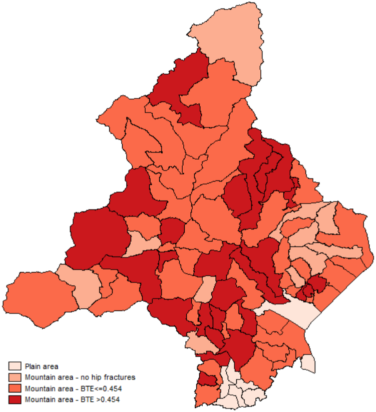
(44% of obs located in this district)



Verbano-Cusio-Ossola

25 municipalities, 12,702 elderly

(33% of obs located in this district)



Summary and preliminary conclusion

- Referring to active ageing, the main idea of work is building a model able to assign efficiency scores to muntain municipalities considering both financial and social constraints
- The model proposed allows policy maker to know where intervening spending financial resources in a more efficient way

Future research

- Validating and testing the model collecting data of the same municipalities of the presented sample and analysing if inter-quartile migration of DMUs occur
- Collecting new input/output data in order to specify better the inefficiency of municipalities
- Introducing political orientation of municipalities, in order to identify if can exist a relation between politics and active ageing consolidation policies

Summary and preliminary conclusion

- Referring to active ageing, the main idea of work is building a model able to assign efficiency scores to muntain municipalities considering both financial and social constraints
- The model proposed allows policy maker to know where intervening spending financial resources in a more efficient way

Future research

- Validating and testing the model collecting data of the same municipalities of the presented sample and analysing if inter-quartile migration of DMUs occur
- Collecting new input/output data in order to specify better the inefficiency of municipalities
- Introducing political orientation of municipalities, in order to identify if can exist a relation between politics and active ageing consolidation policies

Summary and preliminary conclusion

- Referring to active ageing, the main idea of work is building a model able to assign efficiency scores to muntain municipalities considering both financial and social constraints
- The model proposed allows policy maker to know where intervening spending financial resources in a more efficient way

Future research

- Validating and testing the model collecting data of the same municipalities of the presented sample and analysing if inter-quartile migration of DMUs occur
- Collecting new input/output data in order to specify better the inefficiency of municipalities
- Introducing political orientation of municipalities, in order to identify if can exist a relation between politics and active ageing consolidation policies

Thank you for your attention!

Email contatcs

- Greta Falavigna: greta.falavigna@ircres.cnr.it
- Roberto Ippoliti: roberto.ippoliti@unito.it