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Benchmarking performances of research institutions: a measurement model

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BENCHMARKING PERFORMANCES OF RESEARCH INSTITUTIONS: A MEASUREMENT MODEL

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ABSTRACT
Present paper describes a measurement model that allows us a complete and flexible benchmarking among different research institutions (universities and research centres). The completeness of comparison comes out from the use of indicators which concern the main measurement dimensions of research, while the flexibility rises from the possibility to customize the evaluation methods designing new indicators. The model is made up of quantitative and simple measures and performance indicators that work well for all research institutions. It is organized into three measurement levels. These helps us to identify best practices as regards both particular results and overall performances of institutions. The model has been implemented in five Italian research institutions. Implementation proves that measurement model is a complete, simple and useful tool for research institutions performance benchmarking.

Keywords: Scientific Research; Measurement Model; Benchmarking; Case Studies.

INTRODUCTION
Research institutions (universities and research centres) are very different among them. Lack of homogeneity among these institutions is due to different variables of distinction like the field of research, the institutional mission, the organization structure, etc. For this reason, comparing performances among research institutions is often a complex activity.

In literature, the proposed and utilized measures to evaluate research institutions are numerous, but they rarely allow us benchmarking among different institutions. Furthermore, different measurement models have been proposed by experts or government bodies to benchmark universities or research centres. But these models give us only partial benchmarking. In fact, models generally evaluate only some activities (i.e. basic research, applied research), others focus on few measurement dimensions (i.e. human capital, expenses), others fit only for particular contexts.

The aim of this paper is to propose a measurement model that allows us a complete and flexible benchmarking among different research institutions. Such a model is made up of quantitative and simple measures and performance indicators that work well for all research institutions and concern the main measurement dimensions of scientific research.

This paper is organized as follows. Next part deals with a taxonomy of main measurement models for scientific research. In the third part, the methodology we followed to design our measurement model is reported. In the fourth, an in-depth description of the model is proposed.

Then results of the model implementation in five institutions are described (part five), while in the sixth one the complete picture of future implementations of the model is reported. Conclusions deal with practical implications and limitations of the research.

A TAXONOMY OF THE MEASUREMENT MODELS FOR SCIENTIFIC RESEARCH

In the literature on scientific research measurement, bibliometric indicators are usually utilized to measure basic research productivity (i.e. Johnes, 1990; Bourke and Butler, 1998; Groot and Garcia-Valderrama, 2006). Measures like patents, licenses, royalties, etc. are very usual to evaluate results of applied research and technology transfer as well (i.e. Smith and Ho, 2006; Anselin *et al.*, 1996). Furthermore, research institution are often measured with economic indicators like revenues and expenses (i.e. Modell, 2003).

Anyway there are other measures which are important to evaluate research institution performances. Particularly, we refer to measures about human capital (i.e. Coccia and Rolfo, 2002; Cherchye and Abeele, 2005; Geuna, 1998), about structural capital (i.e. Smith *et al.*, 2008; Kastzler and Leitner, 2002) or about relational capital (i.e. Geuna, 1998; Kastzler and Leitner 2002). Training activity measurement is also important (i.e. Johnes, 2006), especially for universities.

Furthermore, there are some authors that propose only quantitative measures (i.e. Modell, 2003), while other authors utilize qualitative measures as well (i.e. Farrington, 2003).

However, many times the measures – quantitative or qualitative – are utilized to evaluate only universities (i.e. Modell, 2003; Cherchye and Abeele, 2005; Johnes, 2006) or only research centres (i.e. Kasztler and Leitner, 2002; Coccia and Rolfo, 2002; Leitner and Warden, 2004; Chu *et al.* 2006; Smith *et al.*, 2008). On the contrary, measures are rarely implemented in both classes of institutions (i.e. Autant-Bernard, 2001).

Data Envelopment Analysis (DEA) is an useful technique to benchmark research institution performance. For example, this technique has been used by Johnes (2006) to evaluate training efficiency of English universities. Nevertheless DEA needs a set of performance indicators as well.

Altogether, literature on research institutions measurement is complete. In fact, there are different measurement methods to evaluate and to benchmark universities and research centres. But these measurements are not enough if someone wants a complete picture of institution performances. There is the need for structured models that consider more measurement dimension, without neglecting simplicity of data collection and results reading.

We have realized a research about measurement models really implemented. We have identified 27 models (Table 1). These are only few models compared with all the ones developed (many of which are not published or consultable actually). For example in Italy, research institutions follow a national measurement model (that is proposed by Commitee for Evaluation of Research, 2003), but they often develop custom models.

Among models we have found, QuESTIO is that one which considers a great number of measurement dimensions and which is implemented both in universities and research centres. But it presents a limit. In fact the model is not made up of few performance indicators, but it includes a large measure set (47 on the whole) that complicates evaluation process.

Besides QuESTIO, there are other four models implemented both in universities and research centres. These ones consider a lower number of measurement dimensions which allow us only partial benchmarking.

Finally, there are another five models for universities measurement and four for research centres measurement that consider a lot of measurement dimensions. Nevertheless some of these models are implemented only in one institution.

Table 1 – Classification of the measurement models for scientific research

N. OF DIMENSIONS CONSIDERED		UNIVERSITIES	RESEARCH CENTRES	UNIVERSITIES + RESEARCH CENTRES
	HIGH	**CNVSU (ITA)**; **ICU Report (SPA)**; **NetVal (ITA)**; University of Bergamo (ITA); University of Udine (ITA) [5]	**ARC IC (AUT)**; **CNR (ITA)**; **DLR (GER)**; IEN (ITA) [4]	**QuESTIO (ITA)** [1]
	MEDIUM	**CRUI (ITA)**; Polytechnic of Milano (ITA) [2]	CMM (AUT); **HBO-institutes (NED)**; JR Explorer (AUT) [3]	**CIVR (ITA)**; **OST (FRA)**; **RAE (ENG)**; **REPP (NED)** [4]
	LOW	**ARWU (CHN)**; **RRTMR (AUS)**; University of Pavia (ITA); University of Trento (ITA); University of Trieste (ITA) [5]	[0]	**CHE (GER)**; **DFG (GER)**; **RCN (NOR)** [3]
LEGEND: Implemented in only one institution; **Implemented in more than one institution**		**APPLICATION**		

ARC IC	Austrian Research Center Intellectual Capital	ICU	Intellectual Capital University
ARWU	Academic Ranking World University	IEN	Istituto Elettrotecnico Nazionale
CHE	Center of Higher Education and Development	JR	Joanneum Research
CIVR	Comitato di Indirizzo della Ricerca Scientifica	NetVal	Network Valorizzazione Ricerca Universitaria
CMM	Center for Molecular Medicine	OST	Observatories des Sciences et des Techniques
CNR	Comitato Nazionale delle Ricerche	RAE	Research Assessment Exercise
CNVSU	Comitato Nazionale per la Valutazione del Sistema Universitario	QuESTIO	Quality Evaluation in Science and Technology for Innovation Oppotunity
CRUI	Conferenza dei Rettori delle Università Italiane		
DFG	Deutsche Forschungsgemeinschaft	RCN	Research Council of Norwegian
DLR	Deutsches Zentrum fur Luft und Raumfahrt	REPP	Research Embedment and Performance Profile
HBO	Hogescholen	RRTMR	Research and Research Training Management Report

RESEARCH METHODOLOGY

A three steps methodology has been followed. First of all, a provisional measurement model has been designed. An in-depth analysis of the literature about scientific research measurement has been realized to complete this step. The main reference journals (especially Research Policy) and 27 measurement models really implemented, of which 14 are international models, have been analyzed. A taxonomy of the measurement models has been realized to identify the reference ones.

Afterwards, 19 experts in scientific research measurement evaluated the provisional model and its measures. The experts belong to 11 different research institutions (Table 2). All these institutions are in Friuli Venezia Giulia region (North East Italy). Focused interview to each expert has been realized. Strengths and weaknesses of the provisional model have been investigated.

Finally, the model that has come out from the interview process has been implemented in five research institutions, two universities and three research centres, in order to test its validity. The cases have been selected among the experts' institutions (Table 2; stained shapes).

THE PROPOSED MEASUREMENT MODEL

The measurement model, we propose to benchmark research institutions, considers the following features:

1. *Completeness of evaluation*: the model considers a set of measures that covers the main measurement dimensions of research institutions.
2. *Objectivity of measurement*: qualitative measures are avoided in order to obtain impartial evaluation and benchmarking among institutions.
3. *Significance of measures*: measures are the most utilized in literature and in implemented models. Moreover, measures have been shared with a panel of experts in scientific research measurement.
4. *Low numerousness of measures*: number of selected measures is small in order to obtain a

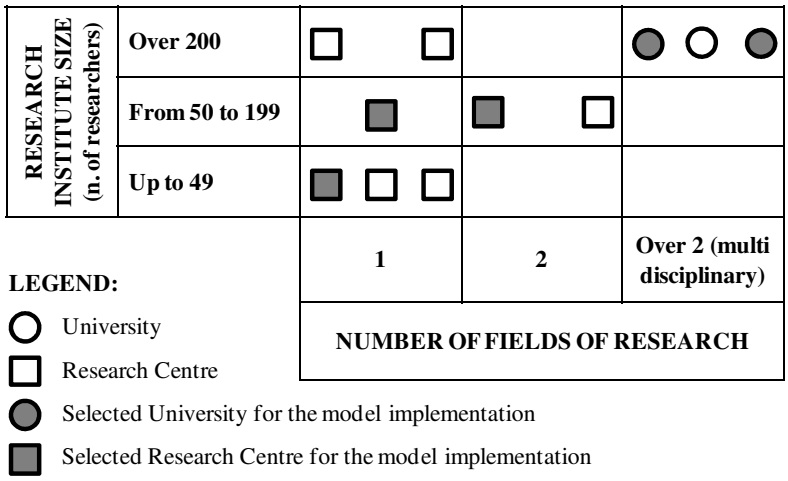
lean model.

5. *Simplicity of data collection*: measures don't need too much waste of resources for data collection.
6. *Quickness of results reading*: elaboration of measures into performance indicators and then into a just one aggregate index allows us easy and quick evaluation of institutions.
7. *Flexibility in designing new performance indicators*: the model includes additional measures which could be used to create specific indicators.

The model is organized into three measurement levels:

- *Level 0 – Quantitative Measures (QM).* It is the higher level of detail for evaluation of institutions. In fact, here the model includes a set of quantitative measures which covers the main measurement dimensions of institutions.
- *Level 1 – Performance Indicators (PI).* Quantitative measures are elaborated in few performance indicators. Indicators are necessary to identify best practices as regards particular performance.
- *Level 2 – Aggregate Index (AI).* It is the lower level of detail for evaluation of institutions. In fact, here performance indicators are elaborated in a just one aggregate index.

Table 2 – The research institutions of the experts



Level 0: quantitative measures

Proposed measures are divided into three macro-dimensions (Table 3):

- Input: it includes measures of human, structural and relational capital and of funds assigned to the institutions for institutional activities.
- Management: it includes measures of how institution works to optimize resources utilization.
- Output: it includes results of institutions as regards main activities (basic research, applied research and technology transfer, training).

The dimensions are measured by a limited number of quantitative measures (32 on the whole). Starting from the most utilized measures in literature and from measurement models we have considered, list of measures has been produced. The list has been refined following the suggestions of experts. Moreover, experts have specified which measures could require a data collection process too much heavy for institutions. We have selected only those measures which require simple data collection for larger set of institutions.

Measures allow us useful and regular benchmarking among different research institution as regards particular results. But at this level benchmarking could be realized only among institutions similar for size. In fact, bigger institutions (that have many researchers) could get better results than smaller ones, because human resources are wider. So, it is necessary to build a set of few and simple performance indicators which consider institution size (Level 1).

Table 3 – The quantitative measures of the model

MACRO-DIM.	DIMENSIONS	SUB-DIMENSIONS	REF.	MEASURES
Input	Assets	Human Capital	1A	N. of (Full and Associate) Professors
			1B	N. of Researchers (for Research Centres) and Assistant Professors (for Universities)
			1C	N. of Postdoctoral Researchers, PhD Students and Research Fellows
			1D	N. of tehnical and administrative staff people
			1E	N. of other employees
		Structural Capital	2	Expense on equipments
			3	Expense on books, journals and database
		Relational Capital	4	N. of researchers of the Institution in mobility abroad and researchers living abroad operating in the Institution (for periods longer than three months)
			5A	N. of research projects in collaboration with Universities (in the same region of Institution)
			5B	N. of research projects in collaboration with Research Centers (in the same region of Institution)
			5C	N. of research projects in collaboration with Universities (in the same country of Institution)
			5D	N. of research projects in collaboration with Research Centers (in the same country of Institution)
			5E	N. of research projects in collaboration with foreign Universities
			5F	N. of research projects in collaboration with foreign Research Centers
	Fundings		6	National funding assigned to the Institution (annual funds provided by Ministries)
			7A	European funding assigned to the Institution for research projects
			7B	Public (national and regional) funding assigned to the Institution for research projects
			7C	Private funding assigned to the Institution for research projects
			7D	Other funding assigned to the Institution for research projects
			8A	European funding assigned to the Institution for training activities
			8B	Public (national and regional) funding assigned to the Institution for training activities
			8C	Private funding assigned to the Institution for training activities
			8D	Other funding assigned to the Institution for training activities
			9	Enrolment fee income for training courses
			10	Total revenues
Management	Expenses		11A	Expense on Professors' salaries
			11B	Expense on Researchers' and Assistant Professors' salaries
			11C	Expense on PhD Students', Postdoctoral Researchers' and Research Fellows' salaries
			11D	Expense on tehnical and administrative staff people salaries
			11E	Expense on other employees' salaries
			12	Overhead expense (buildings heating and air conditioning, cleaning, etc.)
			13	Funding assigned to other institutions for research projects
			14	Expense on infrastructures
			15	Total expense
	Management Systems		16	Institution performance measuring frequency
			17A	Possibility for researchers to deduct a sum of money from research projects (yes/no)
			17B	Possibility for researchers to get payments from extra Institution research activities (yes/no)
			17C	Utilization of merit awards for good researchers (yes/no)
Output	Applied Research & Technology Transfer	Products / Services	18	N. of products and services offered
			19	Revenue from sale of products and services
		Patents	20	Revenue from licensing
			21A	N. of National patents (registered in the last ten years)
			21B	N. of EPO (European) patents (registered in the last ten years)
			21C	N. of World patents (registered in the last ten years)
		Spin-offs	22	N. of spin-off companies (established in the last ten years)
	Basic Research	Pubblications Quantity	23	N. of full papers published on scientific journals (ISI-ranked and non ISI-ranked journals)
			24	N. of full papers published on ISI-ranked journals
			25	N. of books published
		Pubblications Quality	26	N. of times other authors have cited full papers of the researchers of the Institution (only for ISI-ranked journals)
			27	H-index
	Training	Meetings and Seminars	28	N. of people attending meetings and seminaries
			29	N. of meetings and seminaries that Institution has organized
		Didactic	30	N. of students that have attended training courses
			31	N. of hours for training courses
			32	N. of courses

Level 1: performance indicators

We have designed the performance indicators which are made up of quantitative measures (Table 4). Starting from the literature and from experts' suggestions, performance indicators have been built, so as quantitative measures selection.

These indicators, which consider institution size, allow us quick benchmarking among research institutions by little and simple evaluation criteria (moreover indicators are the most suggested in literature and the most utilized by implemented models). So it is possible to identify the best practices as regards particular performance. Indicators have been designed simple to facilitate the understanding of results.

Table 4 – The performance indicators of the model

MACRO-DIMENSIONS	DIMENSIONS	REF.	INDICATORS	FORMULA*	MAIN MODELS THAT PROPOSE SIMILAR INDICATORS
Input		I1	Equiment investiment	$\frac{2}{15}$	CMM (AUT), CNR (ITA), DLR (GER)
		I2	Library investiment	$\frac{3}{15}$	ARC (AUT), CRUI (ITA)
		I3	Fund acquisition	$\frac{10-6}{10}$	CIVR (ITA)
		I4	International opening	$a \times \frac{5E+5F}{5A+5B+5C+5D+5E+5F} + b \times \frac{4}{1B}$	CIVR (ITA)
Management		M1	Research support	$\frac{13}{15}$	CRUI (ITA)
		M2	Management systems utilization	$a \times (17A+17B+17C) + b \times 16$	ICU (SPA), QuESTIO (ITA)
Output	**Basic Research**	OB1	Scientific productivity	$\frac{23+25}{1A+1B+1C}$	ARC (AUT), CNR (ITA), QuESTIO (ITA)
		OB2	Citation rate	$\frac{26}{24}$	ICU (SPA), QuESTIO (ITA), REPP (NED)
		OB3	Scientific visibility	$\frac{26}{1A+1B+1C}$	CRUI (ITA)
	Applied Research	OA1	Patent rate	$\frac{c \times 21A + d \times 21B + e \times 21C}{(c+d+e) \times (1A+1B+1C)}$	ARC (AUT), CNVSU (ITA), CNR (ITA), CIVR (ITA)
		OA2	Company creation	$\frac{22}{1A+1B}$	ARC (AUT), CNR (ITA), DLR (GER), QuESTIO (ITA)
	Training	OT1	Meetings/seminaries success	$\frac{28}{29}$	
		OT2	Training courses success	$\frac{30}{32}$	

*** Numbers refer to column REF. of Table 3** **WEIGHTS:** a, b = 0,5; c = 1; d = 2; e = 3

Level 2: aggregate index

Sometimes it is necessary to benchmark research institutions faster. For example, policy makers – international, national and regional as well – should have to support policies for scientific research with objective and very quick performance evaluations of research institutions.

We propose an aggregate index in order to synthetize benchmarking further. It is made up of the performance indicators (Level 1). There are two steps for index construction:

1. *Normalization of performance indicators*. Each indicator is normalized using the 0% – 100% scale (Normalized Performance Indicator, NPI). The top of scale value (100%) is assigned to institution which realizes the best performance (best practice). Others institutions get values

(among 0% and 100%) proportional to performance of best practice. Process is repeated for every PI.

An alternative approach for PI normalization is that one utilized by European Innovation Scoreboard (EIS) which benchmarks innovation performances among European Countries (Hollanders, 2006). This approach uses 0 – 1 scale and gives value 1 to best practice. But if someone uses EIS approach, he/she must assign value 0 to worst institution. In this way it is likely to damage institutions having less performances, especially if performance difference among best practice and worst institution is very little.

2. *Realization of aggregate index*. For each institution, the aggregate index is realized. It results from the normalization of arithmetic mean of NPIs. To normalize values we have used the same approach used to normalize PI.

It has to be considered that this aggregate evaluation offers just a general indication about which are the best and the worst institutions. In fact, here it isn't possible to identify where institutions excel or have lacks.

Flexibility of the model

The proposed performance indicators (Level 1) are not the only ones. In fact, it is also possible to design specific indicators to measure the particular objectives of institutions. Starting from the quantitative measures, it is possible to create *ad hoc* indicators which, however, allow us rarely benchmark different institutions. So the model could be customized to the measurement requirements of measurers.

Here we give some explanatory examples. If an institution have a large technology transfer activity it should be interesting to measure the revenue from products, services and licensing as measures ratio (19+20)/10 (numbers refer to column REF. of Table 3). Instead, if an institution wants to obtain private funding (i.e. firms) for research projects particularly, it could be utilized the performance indicator 7C/(7A+7B+7C+7D). Moreover, for universities especially, it could be indispensable to measure enrolment fee income for training courses as measures ratio 9/10.

However, when new indicators are designed, it is necessary that they have to be linked to objectives of institution, they have to give simple understanding results and they have to give precise and usable feedback. See Globerson (1985), Fortuin (1988) and Neely *et al.* (2002) for further suggestions about design of indicators.

THE IMPLEMENTATION OF THE MODEL: 5 CASE STUDIES

The model has been implemented in two universities and three research centres in Friuli Venezia Giulia region (North East Italy). The institutions are presented in Table 5.

Table 5 – The case studies selected

INSTITUTION	FIELDS OF RESEARCH	PEOPLE (RESEARCHERS)
University A	• Multidisciplinary	**Over 1600** people among (Full, Associate and Assistant) Professors, Postdoctoral Researchers, PhD Students and Research Fellows
University B	• Multidisciplinary	**Over 360** people among (Full, Associate and Assistant) Professors, Postdoctoral Researchers, PhD Students and Research Fellows
Research Centre A	• Biotechnology • Genetics engineering	**About 190** people among Researchers, PhD Students and Research Fellows
Research Centre B	• Applied physics	**About 130** people among Researchers, PhD Students and Research Fellows
Research Centre C	• Mechanical engineering	**About 15** people among (Full and Associate) Professors and Researchers

The model implementation occurred by January and March, 2008. Data about measures refers to 2006. Data have been collected in the administrative office, general management office and evaluation office (when it was present) of institutions. Some data have not been available at the beginning of data collection and it has been necessary that offices, we contacted, researched them inside to other offices (departments, technology transfer office, institution finance, etc.).

On the contrary, there wasn't any resistance by institutions to give us data. Instead, they showed they were interested in our research, because they consider useful the objective and simple benchmarking among institutions. The institutions think that the model is fit for performance measurement and benchmarking and it is simple to use (even if it is necessary to increase data they just collect with other information).

In Table 6 we report results of the model implementation in the five institutions. Best practices for particular performance are highlighted by a grey box. University B excels for the higher number of performances and it has the higher value of aggregate index (five stars).

To bear out the results of model implementation, University B appears on the Academic Ranking of World Universities (ARWU, 2007). It means that University B is one of the top 500 Universities of the world, while the other university (University A) is not present on ARWU.

Table 6 – Results of the model implementation in five case studies

MACRO-DIMENSIONS	DIMENSIONS	RIF.	INDICATORS	UNIVERSITY A	UNIVERSITY B	RESEARCH CENTRE A	RESEARCH CENTRE B	RESEARCH CENTRE C
Input		I1	Equiment investiment	6%	43%	23%	100%	0%
		I2	Library investiment	22%	100%	38%	20%	0%
		I3	Fund acquisition	41%	34%	92%	7%	100%
		I4	International opening	7%	47%	47%	100%	30%
Management		M1	Research support	65%	4%	100%	24%	0%
		M2	Management systems utilization	100%	100%	50%	50%	100%
Output	**Basic Research**	OB1	Scientific productivity	100%	84%	13%	99%	56%
		OB2	Citation rate	87%	100%	19%	38%	22%
		OB3	Scientific visibility	72%	100%	0%	46%	16%
	Applied Research	OA1	Patent rate	7%	100%	13%	1%	0%
		OA2	Company creation	2%	97%	0%	0%	100%
	Training	OT1	Meetings/seminaries success	0%	56%	29%	100%	94%
		OT2	Training courses success	100%	11%	6%	13%	14%
AGGREGATE INDEX				★★★★	★★★★★	★★★	★★★★	★★★★

LEGEND

★ istitutions with aggregate index from 0 to 20%
★★ istitutions with aggregate index from 21 to 40%
★★★ istitutions with aggregate index from 41 to 60%
★★★★ istitutions with aggregate index from 61 to 80%
★★★★★ istitutions with aggregate index from 81 to 100%
best practice

FUTURE IMPLEMENTATIONS

In the near future, we have to verify the model validity implementing it in other research institutions. Firstly, we'll involve national institutions which work on different field of research from present ones (social and human sciences, earth sciences, etc.). Particularly, we'll verify model fitness for institutions or research groups in operations management. Then, we'll involve international institutions as well.

CONCLUSIONS

We have designed a measurement model to benchmark different research institutions. It is organized into three measurement levels which could be utilized for different evaluations (Table 7). The model is:

- *complete* because it considers the main measurement dimensions of institutions;
- *objective* because it is made up just of quantitative measures;
- *significant* because it has been designed starting from literature, from implemented models and from suggestions of experts on scientific research measurement;
- *simple* because it considers few measures, easy data collection and quick results reading;
- *flexible* because it is possible to design *ad hoc* performance indicators for institution measurement.

Table 7 – Three levels of measurement: features and utilization

LEVEL OF MEASUREMENT	FEATURES	N. OF MEASURES	WHEN USING THESE MEASURES?	WHO COULD USE THESE MEASURES?
Level 0 Quantitative Measures	• Quantitative measures • Absolute values • High level of detail • Simple data collection	32	When someone wants to benchmark research institutes with similar size	Managers of similar research institutes
Level 1 Performance Indicators	• Quantitative indicators • Quantitative measures formulations • Medium level of detail • Simple results reading • Flexibility (as someone can design specific indicators)	13	When someone wants to identify best practices as regards particular performances	Managers of the research institutes
Level 2 Aggregate Index	• Quantitative index • Performance indicators mean • Low level of detail • Simple results reading	1	When someone wants to evaluate the overall performance of the institutes	Policy makers

We have implemented the model in five research institutions (two universities and three research centres) in North East Italy. Institutions think that the model is an useful tool for performance benchmarking. They appreciate the completeness and simplicity of the model.

For future research the model should be implemented in others research institutions (with different size) which work on different field of research from the ones considered by present paper. Certainly, it should be verified if the model works well for institutions or research groups in operations management as well. Furthermore, the model should be tested in international institutions.

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