Qual Quant
DOI 10.1007/s11135-016-0329-y

Artificial neural networks and their potentialities in analyzing budget health data: an application for Italy of what-if theory

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Abstract Since 1992 the Italian local health units (LHU) gained financial independence and became responsible to provide and deliver health care at the local level. Management and financial accounting represent the tool utilized to monitor their net income and the working capital every year. From 2001 on, LHU budget data have being summarized by means of the "income statement". The income statement is considered the most relevant form for the monitoring of healthcare expenditures. A big amount of data have been

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Published online: 24 March 2016

collected after that obligation of publishing the income statement. The application of new methods for a better understanding of relationships among variables would be worthwhile. The development of artificial neural networks (ANNs) can represent a useful tool to analyze the relationships among these variables. The purpose of this paper is showing the potentialities of ANNs and especially of artificial neural networks what-if theory (AWIT) model when applied to health budgetary data. This innovative methodology has been employed, in the present paper, to analyze data from five Italian Regions, carrying out some comparison among them. In short, using one dataset that is defined as being the ideal standard containing the relationships necessary to measure desired outcomes, another dataset can be compared to determine its degree of closeness. We can determine the degree of closeness of the second or treated dataset with the original standard. This is the key concept of the method called AWIT. The descriptive analysis carried out outlines the areas of waste LHU and suggests to develop strategies to contrast an inefficient use of resources.

Keywords Healthcare savings · Artificial neural network · Healthcare costs

1 Introduction

Since the second health reform, implemented in 1992 with the legislative decree no. 502/92, local health units (LHU) gained financial independence and became responsible to provide and deliver health care at the local level. Management and financial accounting represent the tool utilized to monitor their net income and the working capital every year.

From 2001 on, LHU budget data have being summarized by means of the "income statement", formally introduced by Ministerial Decree no. 16/2001. The income statement is considered the most relevant form for the monitoring of healthcare expenditures, that are grouped in some macro aggregates concerning "purchase of goods" (pharmaceuticals, medical devices, non-health good such as meals, etc.), "purchase of services" (pharmaceutical care, in-hospital care, outpatient ambulatory care, rehabilitative care, including remuneration of private practice within public facilities and training of health professionals, etc.), "wages and salaries" (for healthcare staff, healthcare professionals, technical and administrative staff, etc.), other expenses such as subsidies, insurance premiums, legal expenses, depreciation of material assets, and so on.

A huge amount of data have been collected since the obligation of publishing the income statement form has been established: hence, the application of new methods for a better understanding of relationships among variables would be worthwhile.

The development of artificial neural networks (ANNs) can represent a useful tool to analyze the relationships among these variables.

The purpose of this paper is showing the potentialities of ANNs and especially of artificial neural networks what-if theory (AWIT) model when applied to health budgetary data. This innovative methodology has been employed, in the present paper, to analyze data from five Italian Regions, carrying out some comparison among them. In short, using one dataset that is defined as being the ideal standard containing the relationships necessary to measure desired outcomes, another dataset can be compared to determine its degree of closeness. This opens up the possibility of providing one population with some special effect or treatment as in "what if we do x with/to this population?" We can determine the

degree of closeness of the second or treated dataset with the original standard. This is the key concept of the method called AWIT (Buscema and Tastle 2015).

The descriptive analysis carried out outlines the areas of waste and suggests to develop strategies to contrast an inefficient use of resources.

2 Methods

An ANN is an algorithm designed specifically for the processing of information that permits the reconstruction of the rules underlying a certain set of "explicative" data for a specific problem (input) with a set of data (output) for which a correct prediction or a replication of the conditions of informative incompleteness is required (Buscema 1997).

Within Artificial Adaptive Systems, artificial models simulating natural phenomenon can be created through generative algebras. Artificial adaptive systems comprise evolutive systems and learning systems (Buscema 2008).

> La tecnica dell'auto-encoder consente l'ottimizzazione del processo di apprendimento. Lo scopo di questo tipo di apprendimento (auto-encoder) è quello di misurare la capacità di comprensione della logica di un dataset. Si tratta, in altre parole, di una sorta di meccanismo di "calibratura" della conoscenza.

Let DB1 and DB2 be two different datasets with the same types of variables, but possessing different records. The function f () is a non-linear function optimally interpolating DB1, by means of an auto-encoder ANN, with one hidden layer:

$$x_{DB1} = f(h, v^*);$$
$$h = g(x_{DB1}, w^*).$$
$$v^*, w^* = \text{parameters to be estimated by ANN.}$$

After the learning process, the dataset DB2 can be rewritten using the ANN trained on the DB1dataset:

$$x'_{DB2} = f(h, v);$$
$$h = g(x_{DB2}, w).$$
$$v, w = \text{Trained parameters estimated by ANN using DB1.}$$

In this way, the outputs x'_{DB2} represent how each variable of the DB2 dataset is reformulated using the "logic" of the DB1 dataset.

The testing phase of a trained auto-encoder represents the "interpretation" of a dataset (traditionally referred to as the "Testing Dataset", DB2) using the logic present in another dataset (the "Training Dataset", DB1): hence, once a dataset has been chosen as the ideal standard containing the relationships necessary to measure desired outcomes, another dataset can be compared. This opens up the possibility of providing one population with some special effect or treatment as in "what if we do $\underline{x}$ with/to this population?".

It is in this spirit of performing "what-if" analysis, that this method is called AWIT.

Using an auto-encoder ANN we approximate the implicit function of any dataset during the learning phase and assign a fuzzy output to any new input during the recall phase.

A fuzzy output is a value in the range [0.1] in which zero means complete absence or "non-membership" in the output and a one means complete "membership"; any other value indicates the degree of "partial membership" (Buscema 2002).

A prototype of the ANN auto encoder can be seen in Fig. 1.

In order to understand how this mechanism works, let us consider another example.

Let us image a dataset representing the terms (the first two inputs) and the results (the third input) of some summations (Table 1):

It is possible to train an ANN Auto-Encoder to learn from this dataset, in order to abstract the implicit logic of the summation. After the training phase, we can resubmit, as input vector, each training record to the ANN, to verify how much its output repeat correctly the input, in other words, how much its training was good.

Further, we can input to the trained ANN two new records, whose summation is wrong, to check the capability of the system to recognize and correct the error.

This could be the case represented in the Table 2: the results displayed in the third column, that should represent the summation, are not correct.

The ANN is able to reformulate the wrong input in order to generate a more correct result, only driven by its previous experience of the correct training dataset.

Hence, an ANN Auto-Encoder is able to learn the implicit logic of its training dataset and it is also able to adapt to it new testing data.

Recent research improved the auto-encoder ANNs in order to optimize a deep learning process (Hinton et al. 2006), both selecting the fundamental hidden features of a large dataset (Le et al. 2012) and reducing the dimensionality of data (Hinton and Salakhutdinov 2006; Raina et al. 2009; Raio et al. 2012).

Other approaches have tried to use auto-encoders as unsupervised ANNs able to perform supervised tasks (Bengio 2009; Larochelle and Bengio 2008).

3 Results

The AWIT methodology may be employed with LHUs budget data to evaluate if it is possible to replicate the logic governing the best performing LHUs, grouped within Regions, in other contexts.

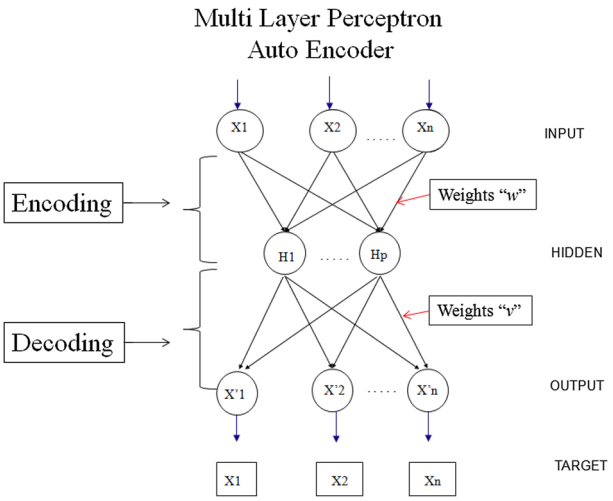

Fig. 1 An example of auto encoder, ready for the training phase

Table 1 An example

First input	Second input	Result
1	0	1
0	1	1
1	1	2
2	0	2
0	2	2
1	2	3
3	0	3
0	3	3
2	2	4
3	1	4

Table 2 An example

First input	Second input	Result
2	1	4
1	3	6

Lombardy, Veneto, Emilia-Romagna, Lazio and Campania were the Regions considered for this case study.

Data employed are those of the income statements for 2010 related to of 66 LHUs, distributed as follows:

- Campania: 7 LHUs
- Emilia-Romagna: 11 LHUs
- Lazio: 12 LHUs
- Lombardy: 15 LHUs
- Veneto: 21 LHUs

Each income statement was made of 401 expenditure categories, but from Campania, for which 353 categories were considered.

These categories may be grouped within the following aggregates, that constitute the inputs used to build the ANN:

1. Value of production;
2. Production costs;
3. Financial revenues and expenditures;
4. Value adjustments to financial assets;
5. Non ordinary revenues and expenses;
6. Financial gross results;
7. Taxes.

According to its budgetary results, Lombardy is the best performing Region, so that it has been chosen as the ideal standard and comparison unit in the analysis.

By measuring the distance between data related to the comparisons Lombardy versus Emilia-Romagna, Lombardy versus Veneto, Lombardy versus Lazio and Lombardy versus Campania, it is possible to determine efficiency and effectiveness of LHUs governance within each Region.

At the end of the training phase, each neural network trained on the LHUs of Lombardy, was used to recall the data of the LHUs located in other Regions. Through this procedure, the likely results that could be obtained if each Region would apply the management model of the Lombardy Region were simulated.

The output provided by the neural network (estimated values) were compared with the actual values reported by each LHU: the variation between estimated and actual output was finally calculated.

Negative values indicate that actual values reported by each LHU and related to the costs of production are smaller than the estimated values: in this case, it is preferable to continue applying the model already used in that Region, without adhering to the Lombardy model.

On the contrary, positive values indicate that costs of production reported by each LHU are higher than those estimated by neural networks. This means that the use of resources is not efficient, because the level of spending is higher than the standard value. In order to achieve a better governance, it should be considered the opportunity to limit those expenditures that present a large and unjustified variability.

3.1 Comparisons region by region

The regions considered in this study have been compared to each other considering the costs of production.

In the comparison between Lombardy and Emilia-Romagna (Fig. 2), the difference between the real and estimated values for production costs (henceforth *delta*, Δ) is positive for all the LHUs; the real values are, therefore, higher than the values estimated through the neural network. The *deltas* are larger for the LHUs Imola, Forlì and Cesena.

The Lombardy management model provides a unit cost of production equal to € 1432; the overall *delta* for Emilia-Romagna is higher than the estimated value and amounts to € 1958 per resident. Hence, the use of resources could be correct applying the Lombardy management model.

In another study, aimed at highlighting the connections between the different LHUs located in some Italian Regions (Mennini et al. 2015), it has been seen as the LHUs of Lombardy present, overall, a network structure with internal relations similar to those of

RESULTS OBTAINED COMPARING THE NEURAL NETWORKS RELATED TO EMILIA-ROMAGNA AND LOMBARDY (401 VARIABLES)				
LHUs EMILIA-ROMAGNA	**PRODUCTION COSTS ***			
	Real Values	**Output ANN Lombardy**	**Delta (Real Values-Output)**	**% Delta/Real Values**
101_LHU-Piacenza	1.99785	1.33850	0.65935	33.00%
102_LHU-Parma	1.83630	1.33080	0.50550	27.53%
103_LHU-Reggio Emilia	1.73525	1.37740	0.35785	20.62%
104_LHU-Modena	1.85241	1.43930	0.41311	22.30%
105_LHU-Bologna	2.05667	1.56480	0.49187	23.92%
106_LHU-Imola	2.14651	1.31220	0.83431	38.87%
109_LHU-Ferrara	1.99360	1.32200	0.67160	33.69%
110_LHU-Ravenna	2.02970	1.64520	0.38450	18.94%
111_LHU-Forlì	2.27967	1.40540	0.87427	38.35%
112_LHU-Cesena	2.16223	1.37650	0.78573	36.34%
113_LHU-Rimini	1.90859	1.34510	0.56349	29.52%
TOTAL	**1.95880**	**1.43240**	**0.52640**	**26.87%**
* weighted for the resident population (thousands of €)				

Fig. 2 *Delta* of production costs for the LHUs located in Emilia-Romagna

Emilia-Romagna. The application of the Lombardy model could, therefore, be an easy solution to solve the problem of waste and bad resource employment.

It is possible to advance similar considerations when looking at the Lazio Region (Fig. 3).

Again, the *deltas* related to the costs of production are positive: while the real cost is equal to € 1996 per person, the estimated cost when the Lombardy management model is applied, would amount to € 1430 per resident. This finding indicates that there are likely waste, which could be corrected. In particular, for the LHUs Roma-A and Roma-E, the *delta* is higher than, respectively, 40 and 50 % (41.37 and 56.88 %).

The application of a management model developed for Lombardy region, would involve lower costs for all LHUs except for the LHUs of Roma-F (−4.68 %).

The scenario changes when other Regions are considered.

For example, in Veneto (see Figs. 4, 5), the LHU Asolo and, to a lesser extent, LHUs Padua and Este, show a negative *delta* (the estimated value is of € 2521 per resident for the ASL of Asolo, instead of the real value of € 1724). The application of the Lombardy model would determine, therefore, a higher expenditure.

For the Region Campania, the only positive *delta* estimated concerns the LHU Napoli 1. In this LHU, the application of the Lombardy model would see an average cost of production equal to € 1510, compared to the current value of € 1929. For the LHUs located in the provinces of Caserta, Benevento, Avellino and Salerno, the *delta* is negative. It could be possible to obtain, on average, a production cost per resident of € 1673, compared to an average real cost of about € 1400.

Despite fewer resources used, it would seem that the management model applied in Campania gives rise, overall, to less waste; it is also true, however, that the analysis has considered a reduced number of LHUs, which, according to the findings of a previous work (Mennini et al. 2015), are not closely related to each other.

4 AWIT and the analysis of specific expenditures: a descriptive analysis

4.1 Comparisons across region

In this section, the analysis is more detailed and focuses on specific expenditures and production costs.

RESULTS OBTAINED COMPARING THE NEURAL NETWORKS RELATED TO LAZIO AND LOMBARDY (401 VARIABLES)				
LHUs LAZIO	**PRODUCTION COSTS ***			
	Real Values	**Output ANN Lombardy**	**Delta (Real Values-Output)**	**% Delta/Real Values**
101_LHU-RM-A	2.24261	1.31480	0.92781	41.37%
102_LHU-RM-B	1.93108	1.34230	0.58878	30.49%
103_LHU-RM-C	2.34295	1.46920	0.87375	37.29%
104_LHU-RM-D	1.84442	1.48710	0.35732	19.37%
105_LHU-RM-E	3.80451	1.33010	1.75441	56.88%
106_LHU-RM-F	1.57632	1.65010	-0.07378	-4.68%
107_LHU-RM-G	1.74966	1.37280	0.37686	21.54%
108_LHU-RM-H	1.82616	1.46270	0.36346	19.90%
109_LHU-Viterbo	1.87971	1.71730	0.16241	8.64%
110_LHU-Rieti	2.04958	1.49920	0.55038	26.85%
111_LHU-Latina	1.64449	1.38520	0.25929	15.77%
112_LHU-Frosinone	1.62428	1.39510	0.22918	14.11%
TOTAL	**1.99633**	**1.43069**	**0.56564**	**28.33%**
* weighted for the resident population (thousands of €)				

Fig. 3 *Delta* of production costs for the LHUs located in Lazio

RESULTS OBTAINED COMPARING THE NEURAL NETWORKS RELATED TO VENETO AND LOMBARDY (401 VARIABLES)				
LHUs LAZIO	**PRODUCTION COSTS ***			
	Real Values	**Output ANN Lombardy**	**Delta (Real Values-Output)**	**% Delta/Real Values**
101_LHU-Belluno	2.27306	1.34770	0.92536	40.71%
102_LHU-Feltre	2.04259	1.89460	0.14799	7.25%
103_LHU-Bassano del Grappa	1.75093	1.41830	0.33263	19.00%
104_LHU-Thiene	1.63011	1.31600	0.31411	19.27%
105_LHU-Arzignano	1.66544	1.34920	0.31624	18.99%
106_LHU-Vicenza	2.09679	1.58470	0.51209	24.42%
107_LHU-Pieve di Soligo	1.69261	1.31470	0.37791	22.33%
108_LHU-Asolo	1.72460	2.52160	-0.79700	-46.21%
109_LHU-Treviso	1.93194	1.76760	0.16434	8.51%
110_LHU-San Donà di Piave	1.76818	1.32810	0.44008	24.89%
112_LHU-Veneziana	2.42958	1.37770	1.05188	43.29%
113_LHU-Mirano	1.69781	1.65440	0.04341	2.56%
114_LHU-Chioggia	2.02652	1.39970	0.62682	30.93%
115_LHU-Cittadella	1.74961	1.35940	0.39021	22.30%
116_LHU-Padova	1.93503	2.00750	-0.07247	-3.75%
117_LHU-Este	1.77010	1.90900	-0.13890	-7.85%
118_LHU-Rovigo	2.30867	1.40270	0.90597	39.24%
119_LHU-Adria	2.20876	1.31380	0.89496	40.52%
120_LHU-Verona	1.81241	1.31840	0.49401	27.26%
121_LHU-Legnago	1.84947	1.45520	0.39427	21.32%
122_LHU-Bussolengo	2.12757	1.69170	0.43587	20.49%
TOTAL	**1.91673**	**1.59551**	**0.32122**	**16.76%**
* weighted for the resident population (thousands of €)				

Fig. 4 *Delta* of production costs for the LHUs located in Veneto

RESULTS OBTAINED COMPARING THE NEURAL NETWORKS RELATED TO CAMPANIA AND LOMBARDY (401 VARIABLES)				
LHUs EMILIA-ROMAGNA	**PRODUCTION COSTS ***			
	Real Values	**Output ANN Lombardy**	**Delta (Real Values-Output)**	**% Delta/Real Values**
201_LHU-Avellino	1.35519	1.77530	-0.42011	-31.00%
202_LHU-Benevento	1.25172	1.50800	-0.25628	-20.47%
203_LHU-Caserta	1.24606	1.60880	-0.36274	-29.11%
204_LHU-Nuova ASL Napoli 1 Centro	1.92963	1.51050	0.41913	21.72%
205_LHU-Nuova ASL Napoli 2 Nord	1.16453	1.51150	-0.34697	-29.79%
206_LHU-Nuova ASL Napoli 3 Sud	1.28581	1.84730	-0.56149	-43.67%
207_LHU-Salerno	1.55530	1.87540	-0.32010	-20.58%
TOTAL	**1.42682**	**1.67377**	**-0.24695**	**-17.31%**
* weighted for the resident population (thousands of €)				

Fig. 5 *Delta* of production costs for the LHUs located in Campania

AWIT methodology allows to make comparisons between the actual values, taken from the income statements of the four regions previously considered (Campania, Emilia Romagna, Lazio, Veneto), and the values estimated through the AWIT model, trained on the data of Lombardy, which is the standard reference.

The figures provide information about the *delta*, i.e. the true value versus the value that represent the output from the trained network.

Overall, positive values for the *deltas* express a level of real expenditure greater than the output estimated through the model; on the contrary, negative values express a level of real spending that is lower than that one produced by the data entered in the trained network, and that should not be modified.

The reported deltas for each Region is the average of *deltas* for the LHUs within the same Region.

The specific items related to the cost of production that have been considered are:

B01025 (B.1.A.4): drugs and materials for prophylaxis (i.e., vaccines);

B01045 (B.1.A.8): prosthetic materials;

B02510 (B.2.B.1.1): laundry services;

B02515 (B.2.B.1.2): cleaning services;

B02520 (B.2.B.1.3): catering services;

B02525 (B.2.B.1.4): expenditures for heating;

B02540 (B.2.B.1.7): services of waste disposal;

B02545 (B.2.B.1.8): telephone bills;

B02550 (B.2.B.1.9): electricity;

B02595 (B.2.B.2): consultations, partnerships, other expenditure not directly related to healthcare;

B07005 (B.7.A): cost of senior staff technical roles;

B07010 (B.7.B): personnel (other technical roles);

B08005 (B.8.A): personnel costs (executive and administrative roles);

B08010 (B.8.B): personnel costs (other administrative roles).

In analyzing the *deltas* of specific expenditure categories within Regions, we considered the five items that show the highest variations:

B01045 (B.1.A.8): prosthetic materials;

B02510 (B.2.B.1.1): laundry services;

B02515 (B.2.B.1.2): cleaning services;

B02525 (B.2.B.1.4): expendirures for heating;

B07010 (B.7.B): personnel (other technical roles).

Regarding the *purchase of prosthetic materials*, we note that Campania is the only Region with a negative delta, equal to −3.7 € per resident, with a value of real expenditure that is, therefore, lower than that obtained by the network trained on the data of Lombardy.

This means that Campania is the only one of the four Regions considered in this comparison for which the adoption of the Lombardy management model would result in a higher expenditure level per resident, comparing to the expenditure currently observed.

If the Lombardy model was applied in this context, the average expenditure would have been 3.7 € per resident more than the amount observed actually.

Looking at each single LHUs in Campania, there are always negative values, except for the LHUs of Salerno and Avellino. On the contrary, in Emilia-Romagna, Lazio and

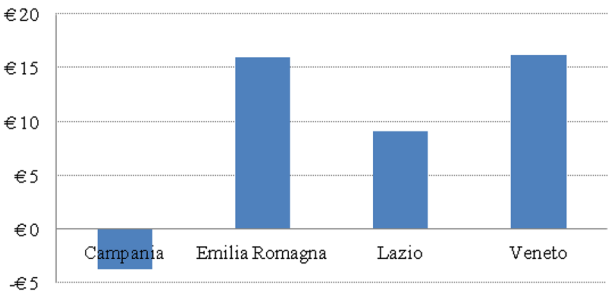

Fig. 6 Average *deltas* for B01045 (B.1.A.8): Prosthetic materials (€ per resident)

Veneto, the use of a management model borrowed from Lombardy would result in a level of expenditure per resident that is lower than the current one (Fig. 6).

The Regions reporting the highest average values of the deltas are Emilia Romagna with 15.9 € per resident and Veneto. with 16.1 € per resident, followed by Lazio with 9.1 € per resident.

All LHUs show positive values of *deltas*. More specifically, the LHUs which report the highest values and that, therefore, might benefit more from the adoption of another management model are LHU Piacenza, with € 24.7 per resident, and LHU Ravenna, with € 27.3 per resident, in Emilia Romagna; LHU Rieti, with € 20.8 per resident, and Latina, with 20.8 € per resident, in Lazio; LHU Venice, with 29.5 € per resident, Mirano with 28.2 € per resident, and Rovigo, with 28.8 € per resident in Veneto.

Concerning *laundry services*, the choice for the management model implemented in Lombardy determines, in all the Regions considered, a significant reduction in the resources that could be employed, comparing to those used in reality (Fig. 7). Specifically, the LHU delta is particularly high for Treviso, with a difference between actual and estimated spending at € 19.5 per resident; Viterbo with 15.8 €, Venice (14.6 €), Forlì (14.1 €), Legnago (9.3 €), Rimini (9.0 €), Ravenna (8.9 €), and so on.

The average *deltas* for the purchases of cleaning services are positive for all Regions.

In this case, the choice of the Lombardy management model would involve a reduced use of resources and would allow to obtain major reductions in the level expenditure (Fig. 8).

Emilia Romagna and Lazio report *delta* values of, respectively 9.5 € and 8.3 € per resident compared with a likely reduction of 3.3 € in Campania and 3.1 € in Veneto. At a micro level, *i.e.* considering the individual LHU, it is possible to identify those with the highest values of the *deltas*: Ravenna (23.7 €), Cesena and Rimini with, respectively, 22.3 € and 22.7 € in Emilia Romagna; Rome-C (18.3 €) in Lazio and, in Veneto Region, the LHU of Belluno (20.0 €) and Venice (18.6 €).

The LHU of Salerno instead, is the only one where the value of the delta is the lowest, amounting to −10.5 €.

The average *deltas* for heating show particularly negative values for Campania and Lazio (respectively −13.5 € and −6,3 €). Such values are close to zero in the case of Emilia Romagna (0.7 €), and significantly positive when considering Veneto (13.3 €)

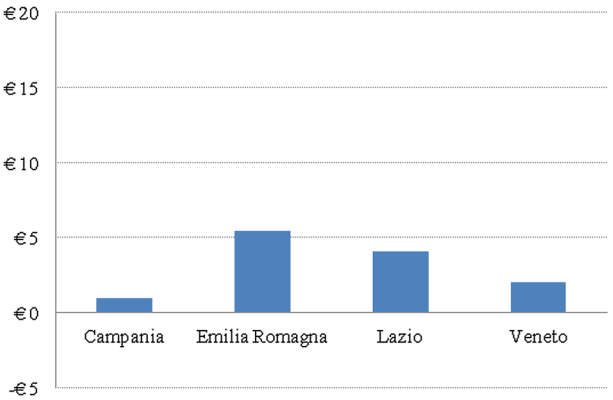

Fig. 7 Average *deltas* for B02510 (B.2.B.1.1): Laundry services (€ per resident)

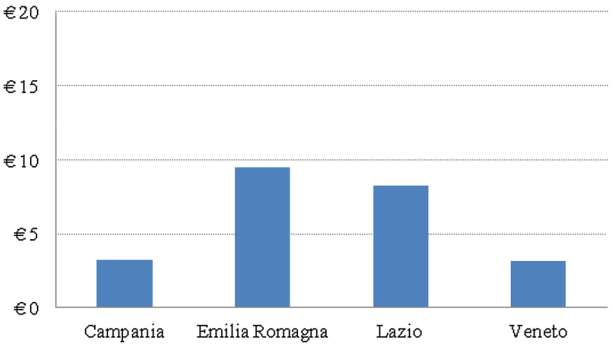

Fig. 8 Average *deltas* for B02515 (B.2.B.1.2): Cleaning services (€ per resident)

(Fig. 9), which could be, therefore, the only Region likely to achieve significant cost reductions by adopting the management model implemented in Lombardy.

In particular, the LHUs of Campania reported values always lower than 10.0 € per resident, but for LHU Napoli 3 South, for which they amounted to −6.4 €.

The LHUs with the highest values in Emilia Romagna are Piacenza and Modena with, respectively, 20.2 € and 11.7 €.

All LHUs in Lazio reported negative values except LHU Roma-D and LHU Roma-H (respectively, 13.0 and 4.4 €). In particular, Rieti and Frosinone reported the lowest values (−20.2 and −16.2 €).

In Veneto, the only LHU to report a negative delta was Este (−3.9 €), while the LHUs with particularly high deltas were Feltre and Rovigo (30.2 and 28.4 € per resident).

As for the *personnel employed in technical roles*, the adoption of the Lombardy model would entail significant reductions in the average expenditure per resident within LHUs in all the Regions considered, except for the Lazio Region, which presents negative *deltas* (−36.6 €), see Fig. 10.

In particular, the LHUs Roma-F, Roma-G, Roma-H and Viterbo present negative values (respectively −88.3 €, −77.6 €, −74.3 € and −72.4 €). It is possible to observe, high variations in the level of spending in the other Regions, as, in Campania, for LHU Napoli 1 (63,1 €), in Emilia-Romagna (Forli and Bologna with, respectively, 59,1 € and −29.3 €), in

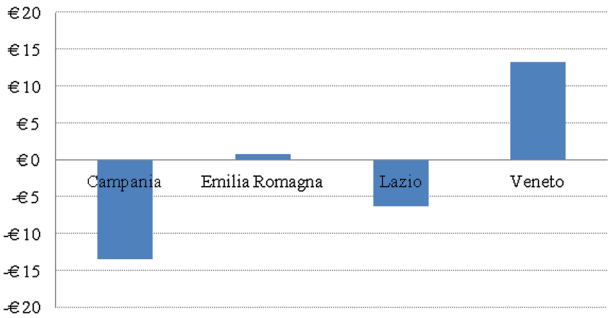

Fig. 9 Average *deltas* for B02525 (B.2.B.1.4): Heating (€ per resident)

Veneto (88.3 € for LHU Belluno, 56.0 € for LHU Asolo and −38.9 € for LHU Bussolengo).

4.2 Comparison among different expenditure categories

The means of the *deltas* related to single expenditure categories have been compared among them, taking into account a region at a time.

Figure 11 shows the average deltas related to production costs for Campania region. In general, the choice to apply the Lombardy model, as simulated by AWIT does not lead to savings or increases in spending particularly significant among the expenditure categories considered. Most of the mean values do not exceed 3.3 € per resident and are not lower than −3.7 € but for the costs related to heating (−13.47 €), consultations, partnerships, and other work expenses (−7.3 €) and the costs of personnel employed with technical roles (16.2 €). Specifically, concerning expenses for heating, LHU Salerno (−18.03 €), LHU Napoli 1 (−17.9 €) and LHU Napoli 2 (−16.8 €) reported real spending significantly that were lower comparing to those produced by the trained network.

Concerning collaborations and other expenditure categories not strictly related to healthcare, the LHUs showing the lowest deltas were Avellino (−9.4 € per resident) and Benevento −9.2 €).

The expenditure for technical staff is characterized by particularly high deltas, that reach the highest values for LHU Napoli 1(63.1 €) and Caserta (17.0 €).

Looking at the situation for Emilia Romagna, the majority of the mean values for the *deltas* are positive (Fig. 12). This means that the use of a management model similar to the standard would determine, for the expenditure categories considered, a significantly lower employment of resources than that actually observed (see, as an example, the purchase of prosthetic materials, that shows an average delta of 16.0 € per resident or the costs for personnel employed in technical roles (13.1 €).

Looking at each LHU within the Region, the highest deltas can be observed for LHU Piacenza (24.7 €) and Ravenna (27.3 €), while the higher deltas for personnel employed in technical roles always occur in Piacenza (28.5 €) and Forlì (59.1 €).

As for Lazio, we note that the only expenditure category relating to the cost of technical personnel, reports a particularly low average *delta* (Fig. 13), amounting to −36.6 € per resident: specifically, the LHUs showing low negative values are Roma-F with—€ 88.3, Roma-G with −77.6 €, Roma-H with −74.3 € and Viterbo with −72.4 €.

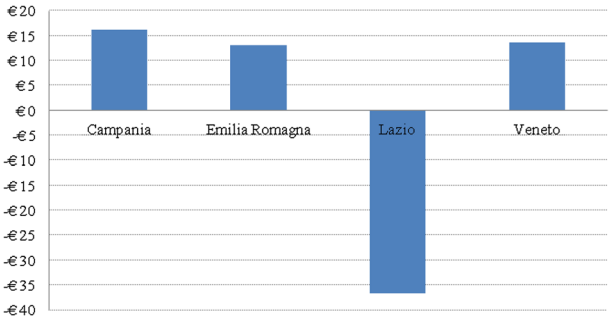

Fig. 10 Average *deltas* for B07010 (B.7.B): personnel employed in other technical roles (€ per resident)

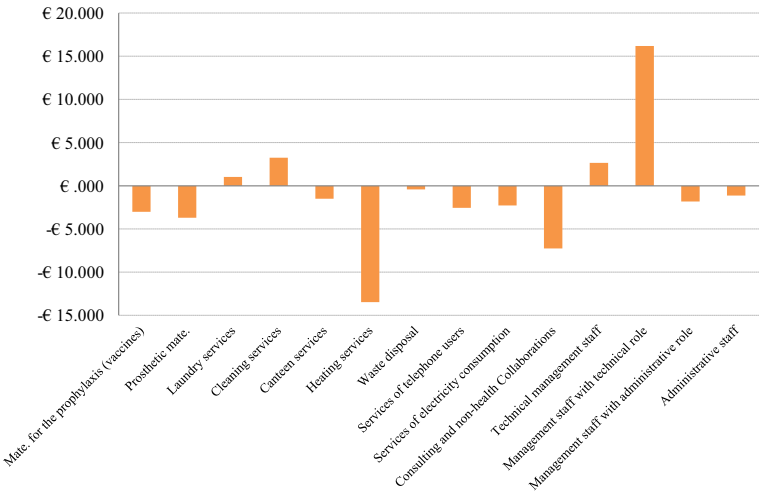

Fig. 11 Mean values for *deltas* related to specific categories of production costs: Campania (€ per resident)

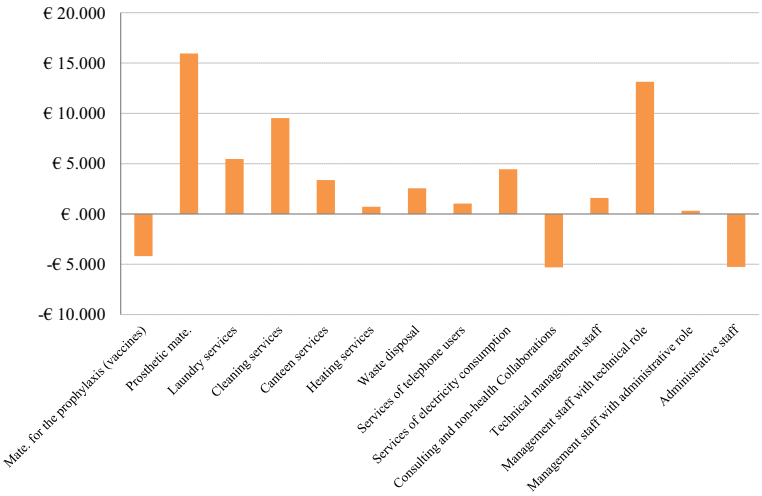

Fig. 12 Mean values for *deltas* related to specific categories of production costs: Emilia Romagna (€ per resident)

Analyzing the data each LHU, we found how there is a wide difference between actual and estimated spending in LHUs Rieti and Latina, both with 20.8 € (purchase of prosthetic materials), LHU Roma-C (25.1 €, related to consultancy expenditures and other services not related to healthcare) and LHU Roma-A, regarding the costs for personnel employed in administrative roles (21.3 €).

Instead, the delta is rather low in the LHU Rieti concerning expenses for heating, and in the LHUs Roma-C and Roma-D, for the cost of administrative staff (mean values for *deltas* respectively, equal to −20.4 € and −21.7 €).

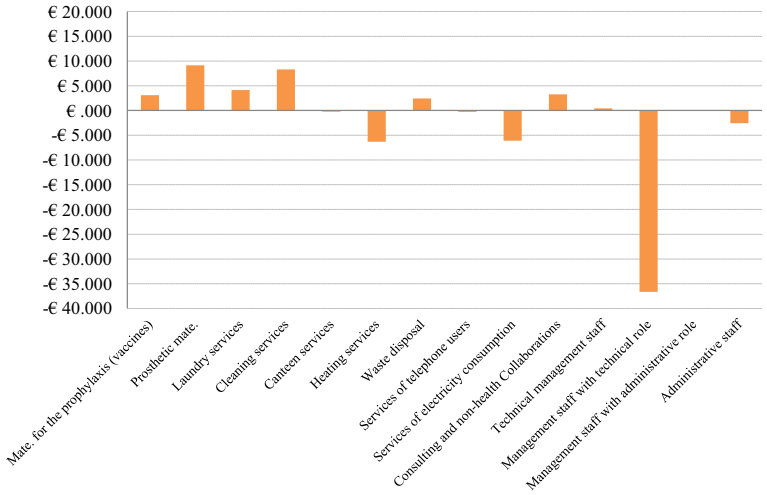

Fig. 13 Mean values for *deltas* related to specific categories of production costs: Lazio (€ per resident)

Through the analysis of the expenditure items of Veneto, we found that the observed expenditure almost always exceeds the average expenditure estimated by the trained network, especially when considering the purchase of prosthetic materials (16.17 € per resident), expenditure for heating (13.3 €) and the cost of technical personnel (13.6 €), see Fig. 14.

With regard to other spending categories, LHU Belluno presents a *delta* of 20.0 € per resident for the purchase of cleaning services, while LHU Treviso shows a *delta* of 20.2 € for catering expenses. On the contrary, LHU Verona Bussolengo reports a delta respectively equal to −22.1 € and −20.2 € for the cost of administrative staff.

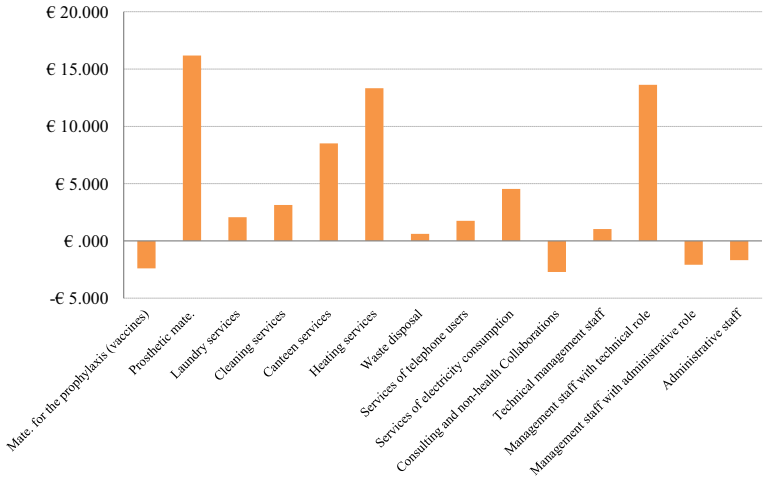

Fig. 14 Mean values for *deltas* related to specific categories of production costs: Veneto (€ per resident)

The results of this second, detailed part of the analysis carried out with AWIT have to be considered jointly with the findings of the first part of the analysis.

Overall, the application of the same management model implemented for Lombardy Region is likely to determine, with few exceptions, significant reductions in LHU expenditure, especially in the Regions Lazio, Veneto and Emilia Romagna.

This does not seem to occur to the LHUs located in Campania, with the exception of some expenses related primarily to personnel and despite the fact that the results of a previous analysis carried out applying AutoCM methodology (Mennini et al. 2015) outlined a strong disaggregation within LHUs in Campania, lack of coordination and fragmentation of the financial-economic behavior within this Region.

5 Conclusions

The present study has to be meant as one of the first applications of models based on neural networks, built with the aim of identifying, for some Italian Regions and LHUs, those ones presenting inefficiency and bad governance.

AWIT can simulate the changes that any input record must undergo in order to fit into the typical features of the training dataset learned previously by an ANN.

The development of ANNs can represent a useful tool to achieve the twofold objective of analyzing the relationships among variables and providing a projection of how an organization (or a regional healthcare service intended as a set of LHUs) would behave in a different context.

Using data from a Region deemed as a benchmark of efficiency as a training database, it was possible to draw conclusions on the performance of other regional healthcare systems through AWIT.

In the case study examined, it has been seen that the application of Lombardy model, with the exception of some few LHUs, would allow to achieve better results with positive effects on the overall effectiveness and efficiency of the system.

Obviously, the same kind of analysis can be performed at a different level, comparing LHUs within the same region, for instance. Furthermore, the analysis can be conducted by adopting various degrees of detail: both single expense items or entire macro aggregates can be utilized as inputs.

The high degree of standardization of income statement forms, together with their deep level of detail, make these accounting tools the ideal input for the promising application of ANN techniques to the study of healthcare expenditure.

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