Managing productivity of public health insurance services

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Abstract: In recent years, considerable emphasis has been given to the determination of the efficiency of public organisations and public service units using the data envelopment analysis method (DEA), which evaluates the relative efficiency of the units under examination. The ability to model both quantitative and qualitative factors in its structure extends the usefulness of the method. Moreover since DEA was initially developed as an efficient measurement tool for non-for-profit situation and since such situations commonly exhibit 'soft factors', the capability to handle such factors becomes a necessity in the field of healthcare system. In this study, we assess the efficiency of the primary healthcare units of the principal Greek public insurance provider the Social Security Institute (IKA).

Keywords: evaluation; efficiency; data envelopment analysis; DEA; health.

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1 Introduction

In the health sector, over the last two decades, in OECD countries, a strenuous attempt to reform the health service systems has been observed, focusing both on the financing of the system and on cost's containment policies in order to reduce the rapid increase in their operating cost and assure the efficient use of resources. Thus an enormous effort is being devoted in studying healthcare performance and producing measures of efficiency. However, the problem of assessing the efficiency of healthcare units presents difficulties towards not only the gain of satisfactorily assessing outcome but also towards the determination and measurement of the provision of care most critical functions' qualitative nature.

Over the past few years, substantial progress has been made in the research and development of efficient methods for controlling the use of healthcare resources. This progress derives either from the use of methods such as DRG's (mainly in the USA) or performance indicators methods, which provide valid measures of input and output (Birch and Maynard, 1986). What is needed however, is the establishment of methodologies, which are capable in investigating in an analytic form the input-output relationships in order to determine the best use of available resources. One such method which has been widely used at the last decade and has provided satisfactory results in the field of measuring the efficiency in public sector units is the data envelopment analysis (DEA). This method measures the efficiency of similar service units by utilising multiple input-output data of quantitative but also qualitative nature. For example, when the method is applied in hospital units, as input variables can be chosen the status of the hospital (public or private organisation) or the type of specialty (general, psychiatric etc.), along with other 'classical' resource variables (such as number of beds, medical staff, etc.). Similarly patient satisfaction as a measure of outcome (output variable) can be incorporated into the method. This constitute the distinguishing feature of DEA because can effectively be applied to the types of non-for-profit settings where the corresponding analysis factors are very often non-economic but qualitative in nature (Cook et al., 1996).

The measurement of the efficiency of health services and the rationalisation of health expenditure are at the heart of general interest since the severe macroeconomic pressures of public spending can cause serious and critical problems in their financial figures.

Common perception is that the lack of scientific methodologies in health services activity is intense in our country, increasing the depletion of resources and minimising the potential for maximising the efficiency and effectiveness of health services in conditions of economic Surveillance and financial crisis

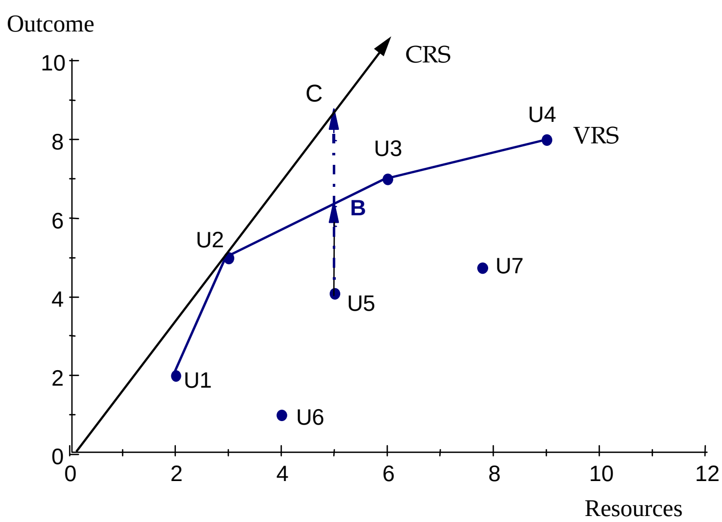
In the present contribution, we attempt to analyse the use of resources and assess the efficiency of the Primary Healthcare Units (PHCUs) of the Social Security Institute (IKA). IKA constitutes the largest public health insurance organisation in the country, providing healthcare to over 50% of the Greek population. The primary healthcare sector of IKA is, in effect, the most significant service provider as the number of visits to local branch units indicate. The study was applied to 78 medical branch units throughout Greece, with data from the year 2005.

The structure of the paper is as follows. The second section is a brief review of the relevant literature. The third section describes the DEA model utilised in this paper and explains its input–output parameters. The fourth section reports and analyses the DEA efficiency scores. The final section summarises our conclusions and presents possible policy implications of the results for policy makers.

2 Literature review and methodology framework

The basic prerequisite of all the methods of productivity measurement is the systemic approach of the productive process, which is obtained by an organisation through an input-output system (Sherman, 1986). The term ‘output’ represents the products or services provided by the units. The term ‘input’, for the main part, represents the resources (human and material) used in producing the output and, secondarily, the environmental factors which influence the formation of the resources (e.g., state of organisation, coverage, location etc.).

Figure 1 PHCUs profiling against frontier (see online version for colours)



The method focuses on the determination of the relatively efficient units, i.e., those units which demonstrate the most successful input-output transformation (as successful is defined the transformation which, while maintaining minimum input obtains maximum output or while maintaining maximum output obtains minimum input). These units constitute the referrals ‘standards’ and ‘envelop’ the other units, thus producing the ‘efficient frontier’ as is shown in Figure 1.

In the above diagram, points U_1, U_2, U_3, and U_4 represent the efficient units that produce the efficient frontier. These units are considered as relatively efficient to those units with the same or less inputs but producing greater outputs. Unit U_2 has the highest number of outcome (output) per unit of resources (input) and thus defines an efficient frontier under constant returns to scale (CRS) that passes through the origin. Relaxing the earlier assumption one can also define an efficient frontier under variable returns to scale (VRS) that is made of units U_1, U_2, U_3 and U_4. Projecting them on the efficient frontier (e.g., U_5B under VRS and U_5C under CRS for unit U_5) makes the scale efficiency of individual units.

Historically the DEA method started with the use of benchmarking and target setting as proposed by Farrell in 1957, but was developed more systematically after 1978 by Charnes et al.. Since then, rapid progress has followed the initial model, not only with respect to the theory but also to its applications. It has been applied, to a wide range of real world problems with significant success (Seiford, 1990) and to numerous organisations such as schools (Thanasoulis, 1996), hospitals (Ozcan and Luke, 1993; Ozcan and McCue, 1996), primary health centres (Sissouras et al., 2000) and universities (Athanassopoulos and Shales, 1997).

Since the introduction of DEA methodology, a considerable number of researchers have applied it in the health service sector. For a review of this literature see Hollingsworth (2003) or Worthington (2004). A large majority of this research has focused on hospitals with primary healthcare services receiving far less attention. This explained for the reason that a hospital is an organisation with clear boundaries, where patients are admitted and discharged. In contrast, primary healthcare delivery is an open, community-based system with unclear boundaries. This difference introduces greater complexity when it comes to the economic modelling of the primary care sector, especially with respect to the appropriate definition of primary care providers’ output (Amado and Dyson, 2008). In another study Amado and Dyson (2009) discussed the nature of primary care and then review the empirical studies that have been carried out in evaluating primary care providers and the various approaches to defining the inputs and outputs that required for a DEA evaluation.

As observed in the relevant bibliography, input-output models attempt to connect medical inputs, which are related to actual resources, with the quantity of medical product in order to capture differences between health units. Based on the formation of such models the assessment seeks to yield information concerning the relative efficiency of individual health units. These efficiency ratings are also connected with factors such as the size, the variability in the severity-criticality of cases, the nature of cases (general medicine, laboratory test, etc.), the epidemiological characteristics of patients, and the ownership status of hospitals. Chilingerian (1995) incorporated output variables related with mortality, morbidity, and patient satisfaction subsequent to therapy while Thanassoulis et al. (1995) focused on quality of care in assessing the provision of perinatal services in the UK. These facts have to be considered in the analytical approach to be chosen. On the other hand, Marathe et al. (2007) argue that regardless of the efficiency measures, health centres efficiency was influenced more by environmental factors than organisational structural factors. The environmental characteristics are important indicators of the demand for care and should include poverty, physician-population ratio, birth rate, uninsurance, crude mortality rate, minority population, region, and rurality. Organisational variables are often considered as design factors such as size, staffing mix, payer mix and integration (i.e., if the health centre is part of a wider healthcare network).

The evidence regarding the performance of IKA primary care centres is very limited. Zavras et al. (2002) examined the efficiency of 133 IKA primary care centres and found that the HCs with the technological infrastructure to perform laboratory and/or radiographic examinations are more efficient. In another study, Kontodimopoulos et al. (2007) compare technical and scale efficiency of primary care centres from the two largest Greek providers, the National Health System (NHS) and the Social Security Foundation (IKA) and found that regarding technical efficiency, IKA performed better than the NHS.

In light of the above, the purpose of this research is to support the relevant literature in primary healthcare evaluation. First this paper attempts to describe an evaluation methodology for PHCUs and give detailed instructions on its implementation. Then the determination of the relative best and most efficient way will introduce documentation on new implementation strategies into the Greek primary healthcare system. Last but not list, according to the results, we propose practical policy implication that concerns the operation of IKA units in both strategic and operational level.

3 Input-output model building

Medical units typically produce multiple outputs using multiple inputs. However the exact nature of this very complex transformation is to a large extent unknown. As observed from the relevant bibliography, input-output models attempt to connect medical inputs, which are related to actual resources, with the quantity of medical product in order to capture differences between health units. Technical efficiency depicts the capability of medical units to transform their inputs into outputs, with a focus on maximising the use of resources. Optimisation is achieved when technical efficiency has been reached such that, no other reorganisation can improve the use of resources. In addition, IKA medical units operate in a non-market environment: market prices of outputs are unavailable and it cannot be taken for granted that the particular units behave as cost minimisers. More specifically, in a competitive market, a firms' inability to cope with shifting demand will result in exit or major restructurings. In contras in a non-market industry (i.e., public services, such as health or education), similar rigidities may persist without exit or corrections, unless managers identify their sources and apply appropriate remedies. Since the outputs are assumed to be non-discretionary, i.e., the PHCUs have no control over the number of patients they treat, it is more appropriate to assume that they have control over the utilisation of resources implying that an input-oriented DEA model should be adopted.

In creating DEA, Charnes et al. (1978) proposed a mathematical programming formulation of the problem of estimating the relative efficiency of operating units such as HCs that produce multiple outputs from a given set of multiple inputs. Hence, in a multivariate sense one has always to assess the efficiency of a set of PHCUs $j = 1,\ldots, n$

that use quantities of inputs $i = 1, \ldots, m$ with x_{ij} the input i of PHCU j to generate quantities outputs $r = 1, \ldots s$ with y_{rj} the output r of PHCU j. The relative efficiency of each PHCU can be obtained by solving the optimisation models in (1) or (2) under constant and variable returns to scale, respectively. In the primal model 1(2) we introduce the following variables: $\lambda j(\mu j)$ represent the amount of PHCU j used, $\theta(\varphi)$ is the efficiency number of the DMU k and $s_r(d_r)$ are slack variables.

$$E_k^{CRS} = \left\{ \begin{matrix} \min\theta \\ \theta, \lambda_j \end{matrix} \left| \sum_{j=1}^{n} \lambda_j x_{ij} + s_i = \theta x_{ik} \forall i; \sum_{j=1}^{n} \lambda_j y_{rj} - s_r = y_{rk}, \lambda_j, s_i, \right. \atop s_r \geq 0 \; and \; \theta \; free \right\} \tag{1}$$

$$E_k^{VRS} = \left\{ \begin{matrix} \min\varphi \\ \varphi, \mu_j \end{matrix} \left| \sum_{j=1}^{n} \mu_j x_{ij} + d_i = \varphi x_{ik} \forall i; \sum_{j=1}^{n} \mu_j y_{rj} - d_r = y_{rk}; \sum_{j=1}^{n} \mu_j = 1, \right. \atop \mu_j, d_i, d_r \geq \lambda \; and \; \varphi \; free \right\} \tag{2}$$

The efficiency of PHCU k is expressed in percentage terms as E_k^{CRS} and E_k^{VRS} respectively. The mechanism for assessing the efficiency of each PHCU k can be summarised as follows:

- One separate linear programming problem is solved for each PHCC within the sample $k = 1, \ldots, n$.
- The empirical frontier is defined using non-dominated PHCUs, i.e., no other PHCU or combination of PHCUs can be found that with the same or less resources can generate more output.
- Inefficient PHCUs are projected on the efficient frontier adopting orientations such as output maximisation (for given resources maximise outputs), input minimisation (for given outputs minimise resource use) or mixed strategies.
- The optimisation problems in (1) and (2) are solved as a two-phased linear programming problem since there is a second phase whereby the objective function of the first phase is held fixed and the slack variables s_r and d_r are sought to be maximised.
- A PHCU is Pareto-efficient (model 1) if and only if $\theta = 1$ and $S_i = 0$, $i = m$, $S_r = 0$, $r = 1\ldots s$. Similarly, in model 2 the pure technical efficiency (VRS) of a PHCU is equal to φ. A PHCU k is Pareto-efficient if and only if $\varphi = 1$ and $d_i = 0$, $i = 1\ldots m$, $d_r = 0$, $r = 1\ldots s$. In addition the pure technical input efficiency of a PHCU cannot be less than its technical input efficiency.

A CCR model is coherent to the peculiarities of the primary healthcare system in Greece. In fact, PHCUs are affected by constant returns to scale since the regional standards tend to align the total costs to the number of patients (Garavaglia et al., 2011). The choice for a CCR model is also supported by Banker et al. (1996), who argued that for small samples, this model should be preferred.

The selection of input/output variables to run the DEA model follows primarily previous studies in the literature (Kontodimopoulos et al., 2007; Mitropoulos et al., 2012). Data availability was also a factor in determining the list of inputs/outputs variables. The adopted definition of PHCU output lies on the basis of assessing their efficiency, solely on quantitative information extracted from the Central Information System of the Ministry of Health and concerns 78 out of 204 IKA PHCUs. It is noteworthy that there is a lack of reliable information concerning the qualitative aspects of health provision of the Greek health system at primary healthcare level. In light of the above, the model that was chosen for the evaluation of the efficiency of PHCUs is described in Table 1.

Table 1 Input-output model

Inputs		*Outputs*	
I_1	No. of medical staff	O_1	Number of acute incidents
I_2	No. of nursing staff	O_2	Number of chronic incidents
I_3	Population covered	O_3	Number of laboratory tests

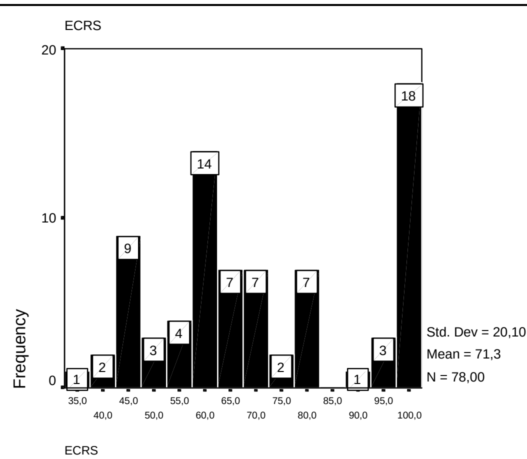
4 Assessing technical efficiency of PHCUs production

The DEA model was applied to 78 PHCUs of IKA and determined the efficiency E^{CRS} of each unit. Moreover, for the units with $E^{CRS} < 100$ (inefficient), it designates the specific targets in input reduction or output increase, in order to become efficient. The empirical findings for E^{CRS} results from the resolution of model (1) are depicted in Table 2. The empirical results will next be presented adopting two alternative segmentation methods of PHCUs, one on the basis of individual operative status and the other on the basis of location since their regional allocation is associated with research questions about policy making implications.

Table 2 E^{CRS} for 78 PHCUs

Statistics E^{CRS}		
N	Valid	78
	Missing	0
Mean	71.31	
Std. error of mean	2.27	
Median	66.74	
Mode	100.00	
Std. deviation	20.10	
Variance	404.14	
Range	63.01	
Minimum	36.99	
Maximum	100.00	
Percentiles	25	57.56
	50	66.74
	75	95.52

Histogram



The above results point out the productivity problem of PHCUs. Specifically 25% of PHCUs confront significant inefficiencies with $E^{CRS} \leq 57{,}565$ and 50% of PHCUs posses

$E^{CRS} \leq 66{,}740$. Contrary only 18 PHCUs appear to be efficient and only a 25% of the total sample presents high productivity process ($E^{CRS} \geq 95{,}520$). In terms of technical efficiency the minimum efficiency was exhibited by 36.99%, while the average efficiency in the case of total assessment was reported below the level of 75%. The latter indicates that PHCUs operations provide considerable space for improvement in terms of cost savings.

The method depicts which of the efficient units are used more frequently as comparators (peers) for the non-efficient ones. This reflects in fact the degree that the input – output transformation of the inefficient units is related to that one of the reference unit. Table 3 presents the efficient PHCUs with the corresponding number of contributions in order to determine the efficient operation levels for the non-efficient medical units.

Table 3 Efficient PHCUs

Efficient PHCUs					
Location		*Peers*	*Location*		*Peers*
1	Kiato	47	10	Kimis	6
2	N.Kosmos	32	11	Naupaktos	6
3	Kiparisias	26	12	Ierapetras	5
4	Agrinio	26	13	Kalitheas	5
5	Trikala	17	14	Xanthis	5
6	Dramas	16	15	Kalamatas	3
7	Pirgos	14	16	Egio	2
8	Megalopolis	11	17	Axioupolis	1
9	Nikeas	10	18	S.Nikolaos	1

This enables policy makers or health managers to single out those efficient units which contribute most, in order to assess the efficiency operation levels of the non-efficient units and study further their organisational or functional characteristic and establish their status as standards. Turning to the inefficient units Table 4 presents the results of the calculated inefficiency level and their regional allocation in two major categories one of large urban centres (L.U.C., up to 150.000 residences, i.e., Athens, Thessaloniki) and the other of rest urban areas (U.A, until 150.000 residences). It must be noted that Athens and Thessaloniki possess the half of total population in Greece and dispose the highest level of medical provision.

For example, the 10th PHCUs (DMU18), in order to become efficient must exceed overall the output mix or reduce input mix by 39.12% (= 100.00 – 60.88), which represent the 'target' distance from the efficient frontier. It is noted that the inefficiency of the examined unit (as extracted by solving the LP model) is determined by the convex combination of the efficient comparators units (peers) no 1, 2, 3, 7, of the Table 3, which are located on the efficient frontier.

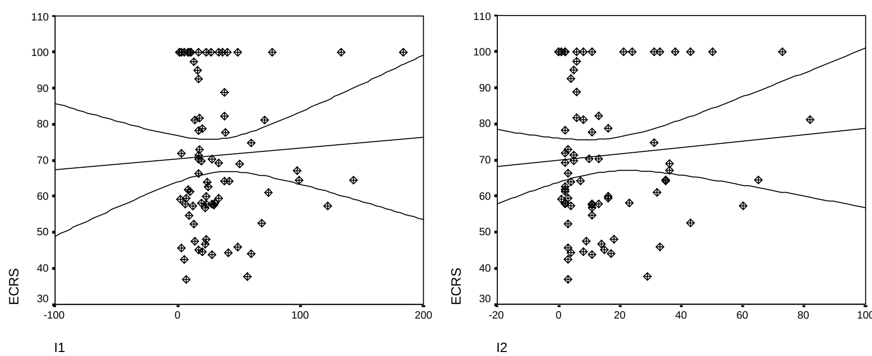
The reporting of the results is made incorporating a spatial differentiation factor that draws upon the differential location of PHCUs. That is, results are reported separately for PHCUs located at large urban centres and urban areas. The analysis of empirical results offers a comparative discussion about the regional production and efficiency of PHCUs which reflects the existence of regional inequalities in health sector in Greece.

The results indicate that in large urban centres PHCUs face an efficiency disadvantage compared to rural areas one's (Table 5). The efficiency differences in two different groups were also verified statistically by means of t-test and Kruskal-Wallis statistical tests. The analysis of the results shows that even though the existing medical coverage exhibits in large urban centres the E^{CRS} does not follow an analogous increase under the hypothesis that the absence of medical staff lead to a decrement of productivity of PHCUs. This argument can be confirmed also the scatter diagrams of Figure 2, between efficiency scores and human resources reflecting the size and operation status of PHCUs. In that figure the left part and right part outline the efficiency variations relative to the medical and nursing staff respectively. It is profound that the efficiency scores of PHCUs are unrelated with both variables of human resources. Conversely urban areas appear more efficient, even though they possess the highest number of beneficiaries per doctor.

Table 4 Inefficient PHCUs

No.	*PHCUs*	E^{CRS}	*Reg. group*	*No.*	*PHCUs*	E^{CRS}	*Reg. group*
1	Lagadas	36.99	L.U.C.	31	Grevena	61.32	
2	S. Sofia	37.78	L.U.C.	32	Lefkada	61.66	
3	Inofita	42.45		33	Argostoli	62.48	
4	Moschato	43.70	L.U.C.	34	Chios	63.87	
5	St. Paraskevi	44.13	L.U.C.	35	Korfu	64.04	
6	Zografou	44.27	L.U.C.	36	Katerinis	64.07	L.U.C.
7	Ptolemaida	44.54		37	Patisia	64.50	L.U.C.
8	Rethimno	45.11		38	Axiou G.	64.50	L.U.C.
9	Soufli	45.68		39	Kilkis	66.34	L.U.C.
10	Alexandroupoli	45.83		40	N.Ionia	67.14	L.U.C.
11	Ano Polis	46.70		41	Serres	69.01	L.U.C.
12	Preveza	47.47		42	Sparti	69.14	
13	Komotini	47.90		43	St.Stefanos	69.82	
14	Aspropirgos	52.23	L.U.C.	44	St.Ierotheos	70.30	L.U.C.
15	Egaleo	52.49	L.U.C.	45	Giannitsa	70.33	L.U.C.
16	Florina	54.57		46	Salamina	71.23	L.U.C.
17	N. Liosia	56.75	L.U.C.	47	Sitia	71.92	
18	Alexandria	57.22	L.U.C.	48	Amalida	72.94	
19	Alexandras	57.40	L.U.C.	49	Chania	74.68	
20	Vironas	57.62	L.U.C.	50	Ilioupolis	77.59	L.U.C.
21	Edessa	57.73	L.U.C.	51	Kastoria	78.24	
22	Koropi	57.80	L.U.C.	52	Arta	78.83	
23	Aliveri	57.86		53	Patra	81.10	
24	Mitilini	58.06		54	Messologi	81.21	
25	Argos	58.18		55	Naousa	81.62	L.U.C.
26	Aliatros	59.15		56	Veria	82.26	L.U.C.
27	Igoumenitsa	59.37		57	Galatsi	88.74	L.U.C.
28	Drapetsona	59.41	L.U.C.	58	Ermioupolis	92.58	
29	St. Alexios	59.86		59	Thiva	94.94	
30	Sq. Attikis	60.88	L.U.C.	60	Amfissa	97.26	

Figure 2 PHCUs regional efficiency assessment and human resources



A logical explanation to the above state is that the inflow of patient cases from large urban centres confront reliability problems in health provision of PHCUs (underutilisation) and they tent to seek healthcare in other forms of medical provision (private or hospital). This result indicates that the centralisation of health provision has led to the creation of very large health supply centres in large urban centres that need to reduce their capacity in favour of urban areas. The lack of qualitative data concerning medical outcomes prohibits any firm conclusions as to whether the concentration of health services in the large urban centres reduces the level of quality of the system.

Table 5 PHCUs regional efficiency assessment

Regions	*No. of PHCUs*	*No. efficient PHCUs*	*Technical efficiency*			
			Mean	*St. deviation*	*Median*	*Min*
Large Urban Centres	32	4	66,063	17,813	64,285	36,99
Urban areas	46	14	74,937	20,976	72,430	42,45
Total	78	18	71,317	20,103	66,740	36,99

5 Conclusions and policy implications

The pressure imposed on health public sector from cost containment efforts has stimulated a strong demand for managerial tools that would identify efficiency in medical service production. The DEA method aims to answer the principal question of any assessment effort, which is whether and to what extent the successful transformation of input to output in a given organisational unit (efficient productive).

The empirical results confirm the well-known problem of the Greek health system concerning the oversupply of health services by large urban medical units. The paradox in this assessment, however, has been that large urban medical units, despite the high demand for services, are significantly better resourced than the corresponding rest urban medical units. Bearing in mind that quality of service and medical outcomes were not part of this research agenda, one can conclude that the concentration of health services in large urban centres does have negative implications on efficiency. It seems that large urban medical units are congested in terms of demand and supply and this constitutes a very promising research agenda for the future. From a policy point of view it is evidence that the optimum use of resources claims a rational reallocation of medical staff with parallel effort to upgrade the quality of medical provision especially in region of large urban centres.

The lack of operation and strategic planning in the IKA network had as immediate effects the incontrollable cost explosion, the emergence of failures and shortcomings in the provision of health services and the creation of serious health inequalities at regional level. Future actions that focus on efficiency improvements in PHCUs are therefore considered necessary.

The system interventions have to be taken both at an operational level and at a strategic level. In terms of operational level it is evident that reallocation of recourses have to be targeted in order to meet the real needs of the population. However these interventions should also address the issues of quality of services and patient satisfaction according to the protocols declared by the efficient units (e.g., staff training according to medical standards, adoption of certain ways - protocols of patent approach) (see: Bosse et al., 2010).

In strategic level is documented the necessity to import gate keeping mechanism in order to establish regulations to patient flows between alternative health providers in public and private sector. This logic refers directly to the introduction of the family doctor ensuring targeted, accurate navigation in the healthcare system, self referrals, avoidance and abuse of resources, establishment of close and long-term relationships, effective implementation of preventive programmes, transparency (sick list).

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References

Amado, C. and Dyson, R. (2008) ‘On comparing the performance of primary care providers’, *European Journal of Operational Research*, Vol. 185, pp.915–932.

Amado, C.A. and Dyson, R.G. (2009) ‘Exploring the use of DEA for formative evaluation in primary diabetes care: an application to compare English practices’, *Journal of Operational Research Society*, Vol. 60, pp.1469–1482.

Athanassopoulos, A. and Shales, E. (1997) ‘An investigation on the cost and value added efficiencies of higher education institutions in the UK using data envelopment analysis’, *Education Economics Journal*, Vol. 5, No. 2, pp.117–134.

Banker, R.D., Chang, H. and Cooper, W.W. (1996) ‘Simulation studies of efficiency, returns to scale and misspecification with nonlinear functions in DEA’, *Annals of Operational Research*, Vol. 66, No. 4, pp.233–253.

Birch, S. and Maynard, A. (1986) ‘Performance indicators and performance assessment in the UK national health service: implication for management and planning’, *International Journal of Health Planning and Management*, Vol. 1, No. 2, pp.143–156.

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Charnes, A., Cooper, W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units', *European Journal of Operational Research*, Vol. 2, No. 4, pp.429–444.

Chilingerian, J.A. (1995) 'Evaluating physician efficiency in hospitals: a multivariate analysis of best practices', *European Journal of Operational Research*, Vol. 80, No. 3, pp.548–574.

Cook, W., Kress, M. and Seiford, L. (1996) 'Data envelopment analysis in the presence of both quantitative and qualitative factors', *Journal of the Operational Research Society*, Vol. 47, pp.945–953.

Garavaglia, G., Lettieri, E., Agasisti, T. and Lopez, S. (2011) 'Efficiency and quality of care in nursing homes: an Italian case study', *Health Care Management Science*, Vol. 14, No. 1, pp.22–35.

Hollingsworth, B. (2003) 'Non-parametric and parametric applications measuring efficiency in health care', *Health Care Management Science*, Vol. 6, No. 4, pp.203–218.

Kontodimopoulos, N., Moschovakis, G., Aletras, V.H. and Niakas, D. (2007) 'The effect of environmental factors on technical and scale efficiency of primary health care providers in Greece', *Cost Effectiveness and Resource Allocation*, Vol. 5, No. 14, pp.1–11, doi:10.1186/1478-7547-5-14.

Marathe, S., Wan, T., Zhang, J. and Sherin, K. (2007) 'Factors influencing community health centers' efficiency: a latent growth curve modeling approach', *Journal of Medical Systems*, Vol. 31, No. 5, pp.365–374.

Mitropoulos, P., Mitropoulos, I. and Giannikos, I. (2012) 'Combining DEA with location analysis for the effective consolidation of services in the health sector', *Computers & Operations Research*, (Article in press: doi: 10.1016/j.cor.2012.01.008).

Ozcan, Y. and Luke, R. (1993) 'A national study of the efficiency of hospitals in urban markets', *Health Services Research*, Vol. 27, No. 6, pp.719–794.

Ozcan, Y. and McCue, M. (1996) 'Development of a financial performance index for hospitals: DEA approach', *Journal of Operational Research Society*, Vol. 47, pp.18–26.

Seiford, L. (1990) *A Bibliography of Data Envelopment Analysis (1978–1990)*, Ver. 5.0, Univ. of Mass., Amherst, Mass.

Sherman, H.D. (1986) 'Managing productivity of health care organizations', in Silkman, R. (Ed.): *Measuring Efficiency: An Assessment of Data Envelopment Analysis*, pp.31–46, American Evaluation Association, Jossey Bass, San Francisco.

Sissouras, A., Mitropoulos, J. and Gounaris, C. (2000) 'Evaluating the efficiency: the case of the Greek primary health care centers', *ICSSHC 2000*, Budapest, Hungary.

Thanasoulis, E. (1996) 'Assessing the effectiveness of schools with pupils of different ability using data envelopment analysis', *Journal of Operational Research Society*, Vol. 47, pp.84–97.

Thanassoulis, E., Boussofiane, A. and Dyson, R.G. (1995) 'Exploring output quality targets in the provision of perinatal care in England using data envelopment analysis', *European Journal of Operational Research*, Vol. 80, No. 3, pp.588–607.

Worthington, A. (2004) 'Frontier measurement efficiency measurement in health care: a review of empirical techniques and selected applications', *Medical Care Research and Review*, Vol. 61, No. 2, pp.135–170.

Zavras, A.I., Tsakos, G., Economou, C. and Kyriopoulos, J. (2002) 'Using DEA to evaluate efficiency and formulate policy within a Greek national primary health care network', *Journal of Medical Systems*, Vol. 26, No. 2, pp.85–92.