Measuring Efficiency of Territorial Commands of PSP

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Abstract

This research comes up in a context where Portuguese Government is under intensive pressure to provide the public services in the most efficient way possible. The main objective of this research was to evaluate PSP's territorial commands efficiency. To measure the relative efficiency we used two DEA (BCC) models in two phases, one being input oriented (IM) and another output oriented (OM). In the second stage the OLS regression model was used to verify the influence of non-discretionary inputs. Variable data from 2008-2011 was obtained from PSP, SIEJ, ANSR and INE's reports. The efficiency results obtained show that there is a considerable variation between individual commands. For the IM model the average technical efficiency was 90.8% and for the OM model the average technical efficiency was 80.5%. The OLS results were statistically significant only for the input oriented model in 2008. A ranking was calculated by combining the technical efficiency results of the two models. The Guarda District command obtained the best combination of technical efficiency score (100%). The ranking mean was 84.82%.

Keywords: PSP; DEA; territorial command; efficiency.

1 Introduction

Every year the Portuguese government invests millions of Euros to provide quality police services to its citizens. An efficient allocation of these funds could save considerable sums of money, and/or improve the quality of services provided by the state. One of the entities responsible for providing security services is the Public Security Police – PSP. Today PSP monitors its own efficiency using the assessment and accountability framework - QUAR. This method starts with the definition of objectives and measurement indicators at the beginning of each year by the National Director. At the end of the year, the values gathered for each indicator are written in QUAR. Then these values are compared with the targets set at the beginning of the year, to measure the level of fulfillment of each one. According to Vaz (2007), in the process of defining the target values of the indicators, this framework uses assumptions that may be oversimplified and thus distance the targets from the reality.

Thus it arises the motivation to seek other approaches to measure PSP's efficiency. The aim of this paper is to measure the police efficiency using a methodology that allows assessing the relative efficiency of PSP's territorial commands, and to do a benchmark analysis. The methodology Data Envelopment Analysis (DEA) introduced by Charnes *et al*. 1978 is one of the most used techniques of performance evaluation, that allows to achieve the objectives set. This approach allows to obtain a measure of relative efficiency from a set of real observations (decision making units - DMUs), allowing the use of various inputs and outputs. The efficient DMUs will get a 100% result. This technique enables to do a benchmark analysis because it defines the frontier of best practices, through the identification of efficient DMUs.

The paper was organized as follows:

-Section 2 presents previous studies in this field, with special focus on the choices of inputs and outputs.

-Section 3 gives a brief introduction to the main concepts of DEA methodology;

-Section 4 defines the data and the models to use in efficiency evaluation;

-Section 5 presents the analysis of results obtained from DEA models;

-Section 6 describes the main conclusions.

2 Literature review

According to Drake and Simper (2005), there are 2 main approaches to measure the relative efficiency through the best practices frontier: the parametric approach (eg SFA - Stochastic Frontier Analysis); and non-parametric approach (eg DEA). The big difference between these two methods lies in how the frontier is estimated. Non-parametric approach (DEA) uses linear programming techniques to involve the DMUs, and in this way define the efficiency frontier. This frontier is constructed by a linear approximation that incorporates the efficient DMUs on the frontier. On the other hand, parametric approach requires that the objective function is built econometrically, using statistical data from the various DMUs. In this case there's usually no-DMU on the efficient frontier, some may be above, and some below the frontier, depending on the type of frontier function.

According to Kuah and Wong (2011), DEA has become popular to evaluate efficiency of non-profit institutions, such as the services provided by governments. In this sense and among other reasons, in this research we applied DEA methodology to evaluate PSP's territorial commands efficiency.

Next are presented some researches where it was applied DEA to measure police services efficiency. The literature in this area can be divided into authors who have chosen to measure the efficiency without checking the effect of non-discretionary inputs - NDIs, those who checked using the two-stage DEA approaches, and those who checked and corrected efficiency results using three-stage DEA.

Diez-Ticio and Mancebon (2002) without checking the influence of NDIs applied an output oriented DEA model to evaluate the technical efficiency (TE) of the criminal investigation activities of Spanish police, taking as DMUs 47 provincial capitals. As outputs they chosen rates of solved crimes, and as inputs they have chosen: the number of police officers; number of vehicles; and the inverse of the population. Carrington *et al.* (1997) and Sun (2002) measured the technical efficiency using a two-stage DEA methodology, of 163 patrols of the Australian State of New South Wales, and 14 precincts of Taipei City, Taiwan, respectively. Carrington *et al.* (1997) used in the first stage an input oriented DEA Model, and they used the following inputs: number of police officers; number of civilian employees; and the number of police cars. As outputs they used: number of arrests; responding offences; serving summon; attending major car accidents and kilometers travelled by police cars. Sun (2002) used in the first stage an output oriented DEA model, with the following inputs: number of police officers; and 3 recorded crimes. As outputs he used the same crimes but as solved crimes. To verify the influence of NDIs on technical efficiency results, in the second stage, these last two researches used a Tobit regression model. It was concluded that, in both researches the OLS results were not statistically significant, and thus they have no influence on the results of efficiency. Gorman and Ruggiero (2008) applied a three-stage input oriented DEA model to measure the technical efficiency of USA's 49 states. The inputs chosen were: sworn officers; other employs; and vehicles. The outputs chosen were: murders; others violent crimes; and total poverty crimes. The NDIs chosen were: single mothers (%); population (millions); poverty (%); population/sq.mile; and labor force (%).The main conclusions were: most states are technically efficient and the NDI population affects positively efficiency results. Wu *et al.* (2010) applied a three-stage DEA model to measure the TE of all precincts of Taiwan. The inputs chosen were: labor cost; general running and operating cost; and equipment purchasing cost. The outputs chosen were: number of cleared up burglaries; number of cleared up violent crimes; number of cleared up for other crimes; number of road traffic accidents; number of general and special services; and resident's satisfaction to public security. The NDIs chosen were: number of public housing units; population; population/sq. kilometer; percentage of unemployed residents; level of education; average household yearly revenue. They concluded that NDIs introduced in the study modify the results of efficiency, although they are statistically insignificant. Aristovnik *et al.* (2013) applied 3 three-stage DEA models to measure the overall efficiency of 11 Slovenia police directorates. Each model used an input, two outputs, and two NDIs. The first model intended to evaluate the overall efficiency (OE) of police activities related with crime prevention, detection and investigation. Public order and overall safety of people and property, and road safety were the other police activities evaluated with the other 2 models. To obtain a unique measure of efficiency the author calculated the geometric mean of the results of the models to obtain a unique measure of efficiency.

3 Methodology

The concepts of frontier analysis and relative efficiency were initially suggested by Farrell (1957). However, the concepts were only useful, when Charnes, Cooper and Rhoades (1978) developed the DEA foundations (CCR model). Charnes *et al.* (1978) proposed that the measure of efficiency of a DMU (E_k) is obtained by maximizing the weighted sum of the output ratio with the weighted sum of inputs, subject to the condition that the similar ratios for every DMU be less than or equal to 1.

$$MaxE_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$s.a. \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, j = 1, \dots, n \quad e$$

$$u_r, v_i \geq 0; \; r = 1, \dots, s; \; i = 1, \dots, m \qquad (1)$$

Where y_{rj} and x_{ij} are positive and represent outputs and inputs respectively, of the DMU_k. The variables $u_r, v_i \geq 0$ represent the weights of inputs and outputs, which will be determined by the solution of this problem, the inputs x_{ij} and outputs y_{rj} are treated as constants assigning values to the weights of inputs and outputs in order to maximize the efficiency of each DMU relative to others. Charnes *et al.* (1978) transformed factional programming formulation (1) in a linear programming formulation by the addition of a restriction which makes the denominator of the efficiency ratio equal to 1 ($\sum_{i=1}^{m} v_i x_{ik} = 1$). Thus, following an input orientation is obtained the next formulation, the model CCR (2).

$$MaxE_k = \sum_{r=1}^{s} u_r y_{rk}$$

$$s.a. \sum_{i=1}^{m} v_i x_{ik} = 1,$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1, \dots., n,$$

$$u_r, v_i \geq 0; \; r = 1, \dots, s; \; i = 1, \dots, m \qquad (2)$$

The dual form of the previous model is represented below:

$$MinE_k = \theta$$

$$s.a. \sum_{j=1}^{n} \lambda_j x_{ij} - \theta x_{ik} \leq 0, i = 1, \dots, m,$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk,} \; r = 1, \dots, s,$$

$$\lambda_j \geq 0, j = 1, \dots., n; \; \theta \qquad (3)$$

In the formulation (3), λ_j represent the weights of inputs and outputs of the corresponding DMU.

To overcome the fact that CCR model assumes constant returns to scale - CRS, Banker *et al.* (1984) by adding the constraint ($\sum_{j=1}^{n} \lambda_j = 1$,), to the model (3) allowed the DEA assume variable returns to scale – VRS (BBC model). This constraint imposes the condition of convexity in the possible ways of how the n DMUs can combine.

In this research we considered three types of efficiency: the overall efficiency – OE (obtained by the CCR); technical efficiency - TE (obtained from the BCC); and scale efficiency - SE will be obtained through the ratio of the measures of OE and TE.

The efficiencies (OE and TE) may be affected by the external environment. To verify the effect of NIDs, Ray (1991) proposed a two-stage DEA model. In the first stage is running a DEA model only with discretionary factors. In the second stage it is used the Tobit regression model, where the results of TE from first stage is the dependent variable, and the independent variables are the values of NDIs. This study was done using two-stage DEA models with an amendment to the Ray (1991) model, since in the second stage we used the ordinary least squares (OLS) estimation model. According to McDonald (2009), OLS regression is more suitable for treating such problems then Tobit model.

4 Data and models definitions

PSP has its territorial device divided into 16 district commands (D), 2 regional commands (Rg), and 2 metropolitan commands (M). The territorial commands were chosen as DMUs to evaluate PSP efficiency. The data collected to the discretionary variables was obtained from activity reports of PSP, ANSR and SIEJ.

The data related to NDIs was obtained from INE.

The first criterion of variable selection was to collect data that was discriminated by territorial command.

Thus, in this study the inputs used were: the number of police officers (POs); and the number of police vehicles (PVs). The outputs used were: the number of recorded crimes (RCs); the number of recorded accidents with victims (RAVs); the resolution rate (RR) of police cases (PCs); and the effectiveness rate (ER) of PCs.

To measure PSP efficiency were applied 2 models, one input oriented (IM), and another output oriented (OM). The IM model has 2 inputs, the number of POs and the number of PVs, and 2 outputs the number of RCs and the number of RAVs. The choices made for this model are similar with those made by Gorman and Ruggiero (2008). In this research, the number of civilian workers wasn't used as input, because in PSP's total staff, they represent a low percentage. The aim of IM model was to evaluate the relative efficiency of the PSP's territorial commands, taking as constant the level of criminality and the level of road accidents, and verifying those commands which had a more efficient use of police staff and police vehicles. Taking into consideration the study of Gorman and Ruggiero (2008), in this research is used another output, the RAVs that is similar to the output, road traffic accidents used by Wu *et al.* (2010). According to them this output intended to represent the proactive/preventive policing. The NDIs used, were: the population (to control the size of the command), the per capita GDP, and the unemployment rate – UR (the last two to control the socio-economic factors). The OM model has the same inputs that the IM model. The outputs used, were: the RR of PCs; and the ER of PCs. In this research, PCs include crimes, transgressions and offenses. The rates RR and ER are calculated using 3 variables: the number of PCs received (in year n); the number of PCs solved (in year n); and the number of pending (PCs) (from the yeas n-1). RR corresponds to the ratio of the number of solved PCs (year n), on the number of PCs (year n). ER corresponds to the ratio of the number of solved PCs (year n), on the sum of the number PCs (year n) with the number of pending PCs (from the year n-1). The OM model is similar with those used by Diez-Ticio and Mancebon (2002). However in this study we didn't use the input inverse of population because later Gorman and Ruggiero (2008) considered his use questionable. In OM model, with the outputs chosen, we tried to represent the capability of each command to deal with all PCs, not only with criminal records. This model uses the population, as only NID. The way the PSP treats PCs was not considered affected by socioeconomic factors. Thus, the aim of this model was to measure the efficiency of PSP in their abilities of treating PCs, maintaining constant the levels of inputs, and searching for the commands that have better yields, in this area. In table 1 are presented the

Table 1: Variable descriptive statistics

Inputs	Mean	Median	Std. Deviation	Minimum	Maximum
Police officers (POs)	955	436	1740	157	8181
Police vehicles (PVs)	213	124	298	47	1396
Outputs					
Recorded accidents with victims (RAVs)	675	347	1132	45	5426
Recorded crimes (RCs)	10068	4395	19213	101	90960
Effectiveness rate (ER)	73,3%	82,6%	25,1%	9,1%	99,5%
Resolution rate (RR)	99,5%	100,8%	23,4%	33,6%	208,8%
Non-discretionary inputs					
Population	250745	126389	421015	30037	1822944
Per capita GDP (m€)	15,015	13,676	2,596	12,618	21,392
Unemployment rate	9,5%	9,0%	2,9%	5,3%	17,3%

descriptive statistics for the data utilized in the models.

5 Empirical results

In the tables 2 and 3, are presented a summary of efficiency results for IM and OM models, respectively. In the model IM, are considered (20×4) DMUs: 20 PSP territorial commands; and the 4 years analyzed (2008-2011). For the model OM are considered (20×3) DMUs, only 3 years are analyzed (2008-2011). Comparing the mean results of OE, TE and SE, presented on tables 2 and 3, we can see that results obtained from IM model are much better than the obtained by OM model. In respect with efficient commands, if we look to OE and SE, we can see that the number of efficient commands is similar for the two models. The TE results from IM model show that there are 42.5% efficient DMUs. On the other hand, the TE results from OM model shows than only 13.3% DMUs were considered efficient. Observing TE results, it is verified that in the OM model was not considered any metropolitan or regional DMU as technically efficient. According the TE results from IM model it is considered 62.5% metropolitan and 25% regional DMUs as TE. This fact suggests that particularly complex (metropolitan and regional) commands obtained better results in the IM model, than complex commands (district). The opposite reasoning is valid for the results OM model.

Table 2: Summary results of the IM model

	Measures of efficiency		
	OE	TE	SE
Mean			
Total	65,5%	90,8%	72,9%
Metropolitan	84,1%	98,5%	85,3%
Regional	73,9%	78,8%	94,2%
District	62,1%	91,4%	68,7%
Std. Deviation			
Total	22,7%	11,5%	24,8%
Metropolitan	11,2%	2,2%	10,0%
Regional	12,0%	14,5%	5,3%
District	23,5%	10,7%	25,7%
Minimum			
Total	26,8%	58,7%	26,8%
Metropolitan	68,6%	94,9%	72,3%
Regional	59,2%	60,2%	85,9%
District	26,8%	58,7%	26,8%
Efficient commands			
Total	7	34	7
Metropolitan	0	5	0
Regional	0	2	0
District	7	27	7
Number of DMUs			
Total	80	80	80
Metropolitan	8	8	8
Regional	8	8	8
District	64	64	64

Table 3: Summary results of the OM model

	Measures of efficiency		
	OE	TE	SE
Mean			
Total	45,2%	80,5%	55,3%
Metropolitan	4,5%	72,0%	5,9%
Regional	18,8%	83,1%	22,7%
District	53,6%	81,2%	65,5%
Std. Deviation			
Total	31,2%	18,3%	33,5%
Metropolitan	2,5%	18,6%	2,0%
Regional	2,8%	7,2%	3,5%
District	29,2%	19,2%	29,2%
Minimum			
Total	1,9%	16,1%	3,7%
Metropolitan	1,9%	47,7%	3,7%
Regional	15,6%	68,6%	18,4%
District	11,8%	16,1%	18,6%
Efficient commands			
Total	5	8	5
Metropolitan	0	0	0
Regional	0	0	0
District	5	8	5
Number of DMUs			
Total	60	60	60
Metropolitan	6	6	6
Regional	6	6	6
District	48	48	48

The results presented on table 4, show the DMUs behaviors relative to the scale, where IRS means increasing returns to scale, and DRS means decreasing returns to scale. The results obtained for the DMUs from the two models, suggests that the majority of the DMUs presents IRS, this means that an increase of a certain order in their inputs levels, causes a greater increase in the output level. The main difference between the returns to scale – RTS, of the two models lies in the tendency of the type of command where the DMUs with DRS appears. In the IM model, DRS behavior is revealed mainly in metropolitan nd regional commands (larger) turn on the OM model DRS behavior reveals itself mainly in district commands (smaller).

Table 4: Returns to scale

		IRS	CRS	DRS
IM Model	Total	56	7	17
	Metropolitan	0	0	8
	Regional	2	0	6
	District	54	7	3
OM Model	Total	42	5	13
	Metropolitan	5	0	1
	Regional	6	0	0
	District	31	5	12

In table 5 are presented the results of the slacks obtained from the IM and OM models, using data of 2008. Slacks in inputs means that is needed reduce his usage. Slacks in outputs means that is needed increment his values. Only DMUs with null slacks are considered efficient in the non-radial sense.

Table 5: Descriptive slacks (2008)

Model	Variable	No. DMUs with slacks	Mean	% Total slacks/ Total (*inputs* or *outputs*)
IM	Police officers	1	0,47	0,1%
	Police vehicles	10	14	6,7%
	Recorded crimes	9	343	3,2%
	Recorded accidents with victims	8	41	6,6%
OM	Police officers	17	527	57%
	Police vehicles	17	112	54%
	Resolution rate	4	2,2%	2,3%
	Effectiveness rate	9	5,1%	7,0%

At this point, it is noted that there are considerable differences in the results of the two models. In OM model, the number of DMUs that have slacks in inputs is much greater number, then in IM model. Furthermore the average of the magnitudes of the DMUs with slacks is also much greater. As regards, the outputs of slacks, it can be assumed that the results for the slacks associated with the two models are in the same row of magnitude.

Table 6: Reference set (2008)

		OM Model		IM Model	
Command	DMU Code	Reference set (VRS)	Frequency	Reference set (VRS)	Frequency
Açores Rg	1-08	19-08		4-08; 17-08	
Aveiro D	2-08	10-08; 19-08		4-08; 8-08	
Beja D	3-08	10-08		10-08; 18-08	
Braga D	4-08		1		12
Bragança D	5-08	10-08			1
Castelo Branco D	6-08	10-08		4-08; 10-08; 18-08	
Coimbra D	7-08	4-08; 19-08		4-08; 8-08	
Évora D	8-08	10-08			6
Faro D	9-08	10-08; 19-08		4-08; 17-08	
Guarda D	10-08		14		2
Leiria D	11-08	10-08		4-08; 18-08	
Lisboa M	12-08	10-08			1
Madeira Rg	13-08	10-08		4-08; 8-08	
Portalegre D	14-08	10-08		4-08; 5-08	
Porto M	15-08	19-08		4-08; 12-08; 17-08	
Santarém D	16-08	10-08; 19-08		4-08; 18-08	
Setúbal D	17-08	10-08			3
Viana do Castelo D	18-08	10-08			6
Vila Real D	19-08		6	4-08; 8-08; 18-08	
Viseu D	20-08	10-08		4-08; 8-08; 18-08	

One of the goals of this study is to enable a benchmarking analysis. On table 6, the results presented are referred to 2008 data. The frequency columns present the number of times that the TE DMUs were used as reference of inefficient DMUs. The reference set columns present the DMUs codes of TE DMUs that should be used as reference for the inefficient DMUs. The reference sets of the OM model are much less diverse than the reference sets of the IM model, this is verified because there are less technically efficient DMUs in the OM model than in the IM model.

In order to define a ranking of PSP's territorial commands, we used the work of Aristovnik *et al.* (2013). He also applied more than one model to measure the performance of Slovenia police. So, it was calculated the TE geometric mean, by year, and after it was calculated the geometric mean of the three years. The results show that district command of Guarda was TE in both models.

Table 7: Ranking of PSP's territorial commands (2008, 2009, and 2010)

Command	TE	Ranking
Guarda D	100%	1
Braga D	97,20%	2
Vila Real D	94,68%	3
Évora D	94,52%	4
Coimbra D	94,39%	5
Porto M	92,94%	6
Viana do Castelo D	90,25%	7
Bragança D	89,26%	8
Portalegre D	88,81%	9
Aveiro D	87,72%	10
Setúbal D	86,36%	11
Castelo Branco D	81,24%	12
Beja D	81,17%	13
Santarém D	79,37%	14
Madeira Rg	79,23%	15
Açores Rg	77,68%	16
Leiria D	76,92%	17
Lisboa M	76,03%	18
Faro D	72,11%	19
Viseu D	56,45%	20
Mean	84,82%	

In tables 8 and 9 are presented the OLS results of the second stage. The results presented in table 9, were obtained running all the data of TE and NIDs, in one time, because when they were run by year, the results obtained were almost the same. The results of IM model, in the year of 2008 were the only ones that has statistically significant at a confidence level of 5% and presented an appreciable level of explanation of the variation of significant technical efficiency of around 56.9%. Focusing the analysis in 2008, the coefficient signal of the population and of the UR, indicates that these NDIs have positive influence on the efficiency results. On the other hand, GDP has negative influence on the efficiency results. Observing table 8 it appears that both the UR and the TE have increased. In 2010, it is noted that the UR starts to negatively influence the results of TE. This may mean that the UR may influence the results of TE in 2 ways, if the average levels of UR remain at low levels, TE is influenced in a positive way. If the average levels of UR are high levels, TE is influenced negatively.

Table 8: OLS results for IM model

	2008		2009		2010		2011	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Population	1,27E-07	5,94E-08	1,10E-07	6,88E-08	5,79E-08	7,71E-08	-3,72E-08	7,21E-08
GDP	-0,03	0,01	-0,02	0,01	-0,003	0,01	0,01	0,02
UR	3,33	1,33	1,11	1,32	-0,05	1,19	-0,34	1,08
R^2	0,569		0,2382		0,0355		0,0391	
Mean	TE	89,4%	TE	91,1%	TE	91,3%	TE	91,6%
	GDP	15,11	GDP	14,64	GDP	15,22	GDP	15,09
	UR	7,3%	UR	9,2%	UR	10,3%	UR	11,4%

Table 9: OLS results for OM model

Variable	Coef.	Std. Err.	t	P>|t|
Population	-1,11E-07	5,62E-08	-1,97	0,053
R^2	0,0628			

Comparing the OLS results of the two models, it becomes clear that the population, in the IM model has a positive influence on the TE results, and in the OM model the population has negative influence on the TE results.

6 Conclusions

We employed two, two-stage DEA models to evaluate the efficiencies of the territorial commands of PSP.

The results showed that the district command of Guarda was the only one that was TE in both models. The mean TE obtained by IM model was 90.8%, where only 17.5% DMUs were TE. This suggests that there are opportunities to improve the use of inputs. The mean TE obtained by the OM model was 80.5%, where only 13.3% DMUs were TE. This suggests that there are opportunities to improve the production of outputs. Related to the other efficiency measures (SE and OE) we observed that the mean results of IM model are always 10% betters than the results of OM model.

The selection of inputs and outputs is the main and most difficult process, in application of the DEA approach. There are opportunities to improve the models used in this study, especially in the outputs side. The definition of these variables was restricted, by the availability of data.

The results obtained, in this paper, can't be seen as an end in themselves. They should be seen as opportunity to begin a process of continuous improvement, through the benchmarking, between the efficient and inefficient commands.

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