Comparative Economic Research, Volume 17, Number 4, 2014
10.2478/cer-2014-0044

AGATA ŻÓŁTASZEK*

Leaders And Followers In The Effectiveness Of Public Safety Services In European States – A Spatial Frontier Approach

Abstract

Public safety is an important factor in both public and private life. Simultaneously it is one of the most regionally diverse sectors, due to historical, cultural, social, legal, and financial differences.Therefore, it is very difficult to compare public safety policies and facilities directly. However, assessment and comparison are crucial factors for defining the best practices and implementing the "learning-from-the-best" policy, which is important in the process of regional development and globalization. Fortunately some quantitative methods, such as DEA (Data Envelopment Analysis) enable this kind of research. DEA allows for analyzing relative effectiveness based on inputs and outputs, without incorporating procedural specifics of public safety. Therefore, the aim of this paper is to perform a regional analysis of the technical effectiveness of public safety systems in European states in 2003 and 2012 by utilizing an optimization method of DEA. Based on the results of this research countries are divided into two groups – effective and ineffective. Countries with effective systems are considered leaders. They present best practices which should be treated as benchmarks for the countries with ineffective systems, i.e. followers.

In the research, inputs of the Data Envelopment Analysis consist of human and financial resources, as these are crucial for the functioning of public safety systems. The outputs are transformations of major crime categories. The analysis has been carried out for selected European countries in 2003 and 2012. This analysis indicates that among the countries with effective public safety systems are Finland, Norway, Romania and Poland.The worst technical

* Ph.D., University of Lodz, Faculty of Economics and Sociology, Department of Spatial Econometrics

efficiency could be observed in Belgium, the UK, Estonia, and Italy, which are underperforming and wasting a large proportion of their resources.

This research indicates that despite many differences among states' public safety policies, improvement and regional development can be stimulated and achieved by implementing the "learning-from-the-best" policy.

***Keywords**: regional analysis, public safety, economics of crime, Data Envelopment Analysis (DEA)*

1. Introduction

Public safety is a very unique sector of an economy. It generally operates on a macro-level, yet its successes or failures are mostly micro-level based. The better it functions, the fewer people notice it is there. It generates no profit and exists solely for the public benefit. This sector is designed to protect people and their property from danger, injury/harm, or damage by preventing crimes, investigating them when they happen, as well as punishing and rehabilitating those who commit them. Public safety is composed of a very wide set of public and private institutions, including law enforcement, a judicial system, a corrections system, as well as fire departments, and private security and environmental safety organizations. (Ortmeier 1998, p. ix) Some of the organizations are managed at the general government level, some on local level, and others operate internationally. However, in terms of analysis, overall both the consequences and policies of public safety are usually considered and examined at the national level.

The main danger posed to public safety stems from crimes, understood as unlawful acts punishable by a state. There is however, no universal definition of a crime; it is a category created by law and therefore defined by the legislation of each country. Some categories, like murder or theft, are commonly perceived as morally wrong and needing punishment, while others vary across states, depending on the legal system. Crimes not only "create" danger but also influence the public perception of safety. Most crimes are very personal and affect, sometimes irreversibly, human life. On the other hand they generate macroeconomic costs, not only through expenses on the public safety system itself, but also as a consequence of the harm done to each person. This issue is often addressed by the field known as economics of crime, which highlights the influence and effect of individual harms in creating public losses to the economy and bringing about a decline in the quality of life. (Benson, Zimmerman 2010, pp.279-350; Eide, Rubin, Mehlop Shepherd 2006, pp.1-2).

Individual and public costs, as well as the threat to personal and public safety, make the public safety sector a crucial one in any society. Simultaneously it is one of the most regionally diverse sectors, due to historical, cultural, social, legal, and financial differences.Therefore, it is very difficult to directly compare public safety policies and facilities. Is a country "safe" because it has high expenditures on law enforcement, its criminal justice system, and its correction system? Is it safer when the number of police officers is higher? Or maybe fewer crimes mean safety? Each of these approaches is correct, but at the same time incomplete. The complexity of safety issues is an obstacle to evaluating the quality and effectiveness of public safety sectors across states. However assessment and comparison are crucial for defining the best practices and implementing the "learning-from-the-best" policy, which is important in the process of regional development and globalization. Fortunately some quantitative methods like DEA (Data Envelopment Analysis) enable these kinds of researches. DEA allows for analysis of relative effectiveness based on inputs and outputs without incorporating procedural and legal specifics of public safety. Therefore, the aim of this paper is to perform a regional analysis of the technical effectiveness of public safety systems in European states in 2003 and 2012 by utilizing an optimization method of DEA. Based on the results of this research countries are divided into two groups – effective and ineffective. Countries with effective systems are considered leaders. They present the best practices, which should be treated as benchmarks for the countries with ineffective systems, i.e. followers. The research inputs of Data Envelopment Analysis consist of human and financial resources, as these are crucial for the functioning of public safety systems. The outputs are transformations of major crime categories. The analysis has been carried out for selected European countries in 2003 and 2012, to allow for spatio-temporal studies. This analysis indicates that the countries with effective public safety systems include Finland, Norway, Romania and Poland. The worst technical efficiency could be observed in Belgium, the UK, Estonia, and Italy, which are underperforming and wasting a large proportion of their resources.

This research proves that despite many differences among states' public safety policies, improvement and regional development can be stimulated and achieved by implementing the "learning-from-the-best" policy. Outcomes of relative measuring technical effectiveness allow to create a pattern relating inputs and outputs, in this case public safety resources versus crime levels and can be used by decision makers of the "less safe" countries to indicate some of sources of the inefficiency. As states with high inputs but poor outputs break this pattern, there should be an extra effort put into establishing the reason for underperforming. These countries should be advised to analyse the quality of their safety policies or external causes like immigration, socioeconomic inequalities, corruption as the plausible culprits of the lost effectiveness.

2. Method

One group of methods which allows for distinguishing leaders and followers is Data Envelopment Analysis (DEA). It was originally designed to optimize the production process by minimalizing inputs with given outputs or maximizing outputs with given inputs. Objects, called Decision Making Units (DMUs), are compared by combinations of inputs and outputs and divided into two subsets:

- ones that fully utilize their production potential and are efficient,
- ones that underperform and are inefficient.

Subsequently, the obtained information allows for an assessment of relative technical efficiency. It is relative inasmuch as the choice of DMUs that should be fairly homogeneous strongly influences results. Therefore, objects should be chosen wisely and carefully. The DEA method allows for researching allocation or economic efficiency, but assessment of technical efficiency is the most common as it provides an insight into the production process, i.e. how inputs are transformed into outputs. (Charnes, Cooper, Rhodes 1978, pp.430-440;Gospodarowicz 2000, pp. 240-246) In order to do this, a separate programming problem maximizing the effectiveness for each DMU is solved as follows:

$$\max_{\mu,\vartheta} \frac{\sum_1^S \mu_{rk} \cdot y_{rk}}{\sum_1^M \vartheta_{ik} \cdot x_{ik}} \tag{1}$$

$$\frac{\sum_1^S \mu_{rk} \cdot y_{rj}}{\sum_1^M \vartheta_{ik} \cdot x_{ij}} \leq 1$$

$$\mu_{rk} \geq 0, \vartheta_{ik} \geq 0$$

$$j,k = 1,\dots,N; r = 1,\dots,S, i = 1,\dots,M$$

where:

DMU_k – k^{th} Decision Making Unit, k=1,...,N,

y_{rk} – r^{th}output of k^{th} DMU, r=1,...,S,

x_{ik} – i^{th} inputof k^{th}DMU, i=1,...,M,

μ_{rk}, ϑ_{ik} – parameters maximizing the effectiveness of kthDMU. (Gospodarowicz 2002, pp.57-70)

However, DEA's biggest advantage is that it provides not only for the division of analyzed groups into leaders and followers, but moreover yields recipes for improving the situation of underperformers. For each inefficient

DMU a efficiency coefficient (Θ) representing a doable proportional increase of outcomes (in an outcome-oriented model), or decrease of inputs (in an input-oriented model) as well as vectors of slacks s– (si– for ith input) and surpluses s+ (sr+ for rth output). Together they allow for obtaining full effectiveness by transforming original vectors of inputs xk and outputs yk as follows:

in input oriented models $(\theta \cdot \mathbf{x}_k - \mathbf{s}^-; \mathbf{y}_k + \mathbf{s}^+)$ (2)

in outcome oriented models $(\mathbf{x}_k - \mathbf{s}^-; \theta \cdot \mathbf{y}_k + \mathbf{s}^+)$. (3)

For years DEA was treated as a semi-econometric method, but lately it has been granted an estimator status. Assuming that there is indeed an effectiveness frontier defined by the production processes of all leaders on the market and the linear combination of their input-output structure, the DEA approach provides an estimate of it. Therefore, Data Envelopment Analysis methodology has been developing rapidly in many directions. It has been widely used not only in production in the classical meaning, but also in a wide range of social policies, transportation, and regional science research (the frontier is often referred as the spatial frontier) as long as there is a decision-making process considering some kind of inputs and outputs for homogeneous objects that can be compared.

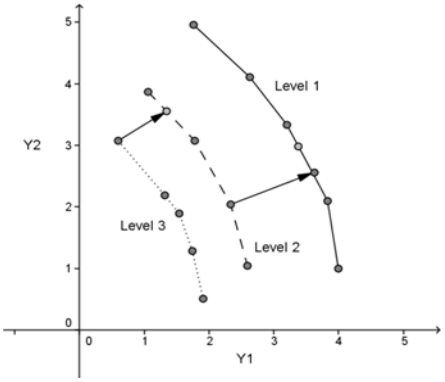
Not only has the spectrum of topics changed. The classical DEA is still very useful, but the latest modifications widen its possibilities. Most of them eliminate some vices in the original approach. The new methodology includes:

- Super-efficient (Outlier robust) DEA that countermeasures for exceptional DMUs that lie above the normal efficiency frontier, (Kourtit, Nijkamp 2013, pp.761-764)
- Distance Friction Minimization (DFM) DEA that allows for optimizing each input and output separately instead of using a common efficiency coefficient, (Suzuki, Nijkamp 2011, pp.1-5)
- Context-Dependent (CD; Stepwise improvement) DEA that assumes the gradual improvement of DMU's effectiveness.

The latter incorporates a realistic idea that it is easier to improve by a little than by a lot. The CD approach assumes that the objects may be divided into more than two subsets. Each subgroup and its linear combinations defines a different level efficiency frontier. The first level frontier consists of objects effective in the classical DEA way, that is the best DMUs that, compared to others, transform 100% of inputs into outputs. The next level frontier is drawn by DMUs which are better than some, but not good enough to get to level one. Their goal should be to improve in the future so they can upgrade to the first frontier. Third level DMUs should aim at achieving the second level, which is

not so distant, instead of trying to reach first level all at once. Therefore, objects on a given frontier should try to improve one level at a time (see Fig.1). This approach is quite tangible, as in many cases the input-output transformation is only a few percentage points below the nearest upper frontier, while attaining level one may require an unrealistic correction by dozens of percentage points. Therefore, the improvement is archieved step by step, hence the name - Stepwise improvement DEA. The process is based not only on the combined situation of all objects, but also on the structure of each level frontier - Context-Dependent DEA.(Suzuki, Nijkamp 2011, pp.5-6; Seiford, Zhu 2003, pp. 397-408).

Figure 1. Illustration of Context-Dependent (CD; Stepwise improvement) DEA in a output oriented model and three-level efficiency frontiers



Source: author's own in GeoGebra.

This approach is especially useful for regional comparisons where decision making is controlled by noneconomic and exogenous factors. Any changes must be not rapid, but introduced wisely and carefully, i.e. through an evolution rather than a revolution. On the other hand, many regional social issues like health, transportation, and of course public safety are not a production process per se. Nonetheless material, financial, and human resources are utilized to supply a public good and perform a social function. Effects are often non-material and qualitative rather than quantitative, but they can still be measured. Therefore, in a broad sense, some inputs are used to obtain a particular outcome, so a production occurs. All regions are unique, yet they operate under the same restrictions. They must use their resources as effectively and efficiently as possible in order to obtain goals defined by law, social policy, and public expectations. They are governed by elected representatives who are chosen by the people and for the people. As such they can be treated as a homogenous object and compared by DEA methods and used for establishing a spatial efficiency frontier. (Galinienė, Dzemydaitė 2012, pp. 390-399)

3. Data

In order to assess and compare the effectiveness of public safety sectors by incorporating Stepwise improvement DEA, 29 European states were chosen: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom. The basic inputs on public safety consists of human and financial resources. Eurostat offers the number of police officers, which then has been divided by the population of each state to obtain the number of police officers per 100,000 inhabitants. The second input chosen was general government expenditures on public order and safety as a percentage of GDP. In order to present outputs of public safety, major groups of crimes were selected as representative of the true state of safety in each state:

- Homicide;*"This is defined as intentional killing of a person, including murder, manslaughter, euthanasia and infanticide. Causing death by dangerous driving is excluded, as are abortion and help with suicide. Attempted (uncompleted) homicide is also excluded. The counting unit for homicide is normally the victim (rather than the case)."*(Eurostat Crime and criminal justice);
- Violent crime;*"This includes violence against the person (such as physical assault), robbery (stealing by force or by threat of force), and sexual offences (including rape and sexual assault)."*(Eurostat Crime and criminal justice);
- Theft of a motor vehicle;*"Motor vehicles include all land vehicles with an engine that run on the road which are used to carry people (including cars, motorcycles, buses, lorries, construction and agricultural vehicles, etc.)."*(Eurostat Crime and criminal justice);
- Drug trafficking; *"Drug trafficking includes illegal possession, cultivation, production, supplying, transportation, importing, exporting, financing etc. of drug operations which are not solely in connection with personal use."* (Eurostat Crime and criminal justice).

The number of each crime category was standardized by establishing its occurrence per 100,000 inhabitants in a state. All data was obtained from Eurostat for years 2003 -2012. This combination should allow for assessing how safe or dangerous a country really is, and if the inputs are effectively utilized compared to the number of crimes which occur.

The spatial distribution of inputs is fairly even. On average a country spends 1.8% of its GDP on public order and safety. The lowest expenditures of

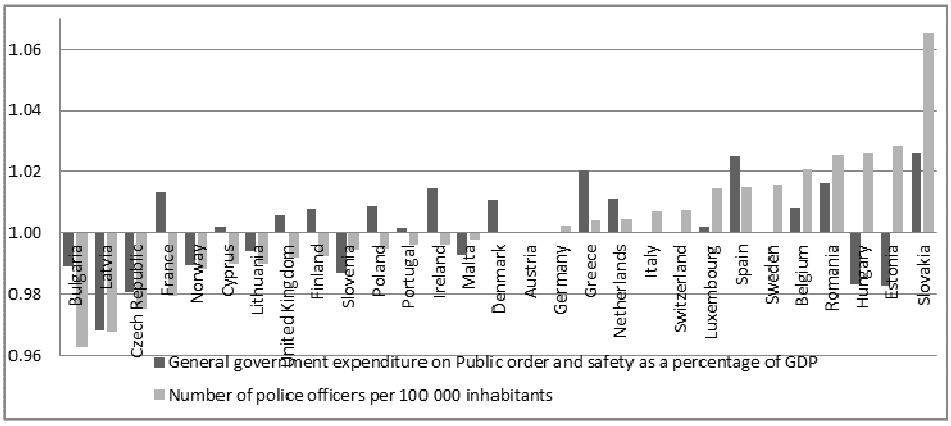
1% were observed in Denmark in 2002 and in Norway in 2012. The highest ones were in Bulgaria (2.8% in 2003, 2.54% in 2012). The variation coefficient is rather low – 23%. Over time changes in public expenses were small: in nine states expenditures decreased (the biggest yearly drop was in Latvia, by 3% of general government expenditures on public order and safety in GDP), in five they did not change (Austria, Germany, Italy, Sweden, and Switzerland), and in fifteen they increased (the highest in Slovakia, by 3% every year of expenditures in GDP). With respect to the police force, there were almost 340 officers per 100 000 inhabitants in each state, the median was a little lower, around 300-325 officers. The fewest policemen were in Finland (159 in 2003 & 149 in 2012) and the most in Cyprus (669 in 2003 & 611 in 2012). The percentage standard deviation was between 33% and 37%, decreasing over time. In fourteen countries the number of officers declined (the biggest decline in Bulgaria, by 4% each year) and in fifteen countries the number increased (the most in Slovakia, yearly by 7%). Therefore, both inputs were increasing at fastest pace in Slovakia. (see Table 1 & Fig. 2)

Table 1. Statistical measurement for expenditures on public safety and number of police officers in 2003 and 2012

Input	General government expenditure on public order and safety as a percentage of GDP		Average number of police officers per 100 000 inhabitants	
Year	2003	2012	2003	2012
Mean	1.78	1.8	336.1	338.13
Median	1.7	1.8	303.14	324.02
Minimum	1	1	159.19	148.8
Maximum	2.8	2.54	668.75	610.55
Variation coefficient	23%	23%	37%	33%

Source: Own calculations based on Eurostat database.

Figure 2. Average change rate of public safety expenditures and number of police officers in Europeans states in the years 2003-2012



Source: author's own based on Eurostat database.

The safety of citizens is measured by the number of crimes, however, the severity and danger level depends on the offence. Generally, there were very few homicides compared to other crimes. In 2003 there averaged 2.44 murders per 100 000 people in Europeans states, and 1.64 in 2012. The median was a bit lower, so half of the analyzed countries averaged no more than 1.52 (in 2003) and 1.08 (in 2012) per 100 000 people. The fewest homicides were registered in Malta (none in 2003) and Norway (0.54 per 100 000 people in 2012). The highest average murder rates were in Lithuania (11.22 in 2003 & 6.55 in 2012 per 100 000 people). The regional variability was quite high, as the variation coefficient was 118%. Fortunately the number of homicides per 100 000 inhabitants was systematically declining in 24 out of 29 countries, the most in France, by 10% every year. There was an annual increase in Cyprus (0.5%), Greece (4%), Austria (5%), and Malta (from 0 in 2003 to 2.16 in 2012). Violent crimes, which include most homicides as well as assault, robbery, and sexual offences, were much more common. On average there were 367 cases per 100,000 inhabitants in Europe in 2003 and 385 in 2012. The lowest violent crime rate (per 100,000 inhabitants) was noted in Romania (29 in 2003 & 31 in 2012) and the highest in the United Kingdom (1,720 in 2003 & 1,213 in 2012). As the maximum is 40 to 60 times higher than the minimum value, the mean is much higher than the median, and the percentage standard deviation of over 90% demonstrates that there is a considerable diversity among European states. Besides, the UK as well as Belgium and Sweden had over 1,000 violent crimes per 100,000 inhabitants. In fifteen states the number of these offences decreased every year, the decreasing the fastest in Latvia – 8% per year. In the remaining 14 countries police statistics showed a systematic increase, up to 12% per year in

Estonia. Car theft was one of the most common crimes in Europe. In 2003, on average 253 vehicles were stolen per 100 000 people, and in 2012 this average rose to 501. This problem was the smallest in Romania (5.2 in 2003) and Slovakia (97 in 2012), while the most cars were stolen in Sweden (752 in 2003) and Denmark (1,247 in 2012). Although the value for Romania in 2003 seems rather suspicious, there is no way of verifying it. The diversity among states is moderate, since the variation coefficient is the lowest among crimes and decreasing over time (75% in 2003 to 63% in 2012). Unfortunately, the number of motor vehicle thefts rose in 24 of 29 states, up to 40% per year in Greece. Small declines were registered in Norway 4% per year), Finland (3% per year), Sweden (2% per year), the Czech Republic (1% per year), and Slovakia (0.2% per year).

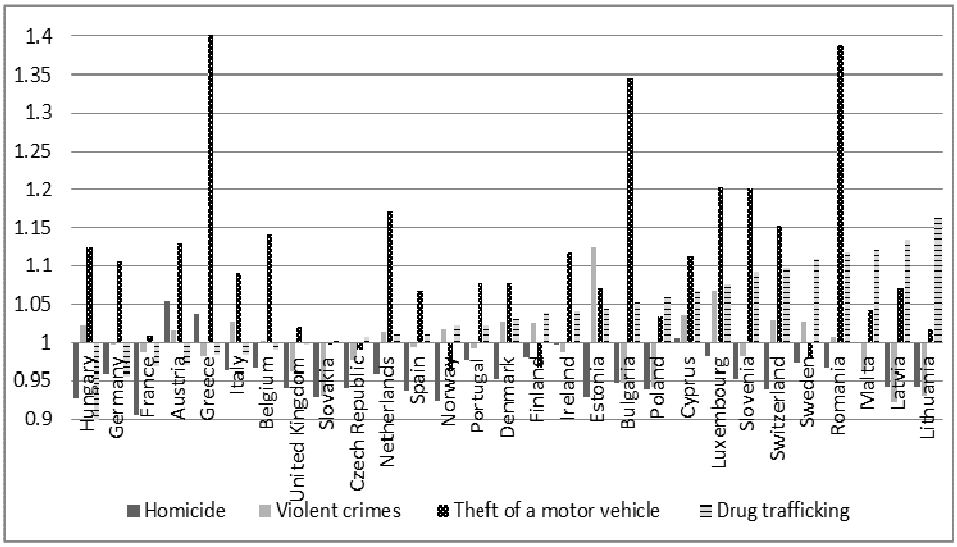
The last offence incorporated into the research was drug trafficking. On average in each state there were 68 cases in 2003 and 98 in 2012 per 100,000 inhabitants. The median is noticeably lower than the mean which, together with the variation coefficient of 110%-117%, suggests a great deal of regional diversity in this area. The fewest drug-related crimes were registered in Romania (5.2 in 2003) and Hungary (5.7 in 2012), and the most in Norway (355 in 2003) and Luxembourg (492 in 2012). Therefore, the maximum was 68 to 86 times higher than the minimum. This shows that there is a strong disproportion in Europe with respect to drug trafficking. Moreover, only eight countries had a decrease in drug-related crimes, with the largest decrease taking place in Hungary (18% yearly) and Germany (4% yearly). Most states recordede an increase in drug trafficking, up to 16% per year in Lithuania. (see Table 2 & Fig.3).

Table 2. Statistical measurement for crime categories in 2003 and 2012

Crime	Homicide per 100,000 inhabitants		Violent crimes per 100,000 inhabitants		Theft of a motor vehicle per 100,000 inhabitants		Drug trafficking per 100,000 inhabitants	
Years	2003	2012	2003	2012	2003	2012	2003	2012
Mean	2.44	1.64	367.41	385.31	253.39	501.02	67.55	97.83
Median	1.52	1.08	247.31	233.7	211.65	440.745	43.925	62.13
Minimum	0	0.54	29.04	30.62	5.21	97.37	5.23	5.74
Maximum	11.22	6.56	1720.11	1213.12	751.60	1247.48	354.81	492.14
Variation coefficient	118%	94%	98%	92%	75%	63%	110%	117%

Source: Own calculations based on Eurostat database.

Figure 3. Average rate of change in crime categories per 100 000 inhabitants in European states in the years 2003-2012



Source: author's own based on Eurostat database.

Generally, as the change rate in inputs is spread among countries the crime rates, excluding homicide, increased. This raises the questions: Which public safety systems are technically effective? Does the effectiveness vary over time?

4. Results

In order to verify the effectiveness of public safety systems in European states over 10 years – 2003-2012 – a Context-Dependent or Stepwise improvement input-oriented DEA was employed. The analysis was carried out independently for the year 2003 and then in 2012. Moreover, since in this case outputs are negative, as crimes represent public danger rather than public safety, they cannot be introduced into the DEA optimization. Therefore, each variables' value was inverse. In Malta, in 2003 there were no homicides, therefore, inversion was not possible so it was assigned a 2, which is higher than the maximum value for other states. Since the inputs are controlled by the states, while outputs are mainly exogenous, an input-oriented model was chosen.

4.1. Results for 2003

In 2003 the states were divided into four groups defining the sequential spatial frontier levels. There were nine states that had managed to fully utilize their inputs: Austria, Denmark, Finland, Luxembourg, Malta, Norway, **Poland**, Romania, and Sweden. These countries had efficiency coefficients of 100% and in their current situation could not do any better. The second level frontier is defined by nine DMUs: Bulgaria, Cyprus, France, Germany, Greece, Ireland, Slovakia, Slovenia, and Switzerland. Their performance was not outstanding, however, they did fairly well compared to other states. Their effectiveness was very diverse ranging from 44.4% in Bulgaria to 94.1% in Switzerland. In the former both inputs, expenditures and number of police officers should have been lower by 56%, additionally the police force should have been diminished by 42.6 officers per 100,000 inhabitants. Even then the number of crimes committed should have been lower: homicides by 3.7 and drug trafficking by 3.74 incidents per 100,000 inhabitants. In Switzerland the efficiency coefficient suggests that only 6% of inputs were wasted. A slight correction of expenditures was needed – 0.11% of the GDP less than is currently spent. Subsequently the number of car thefts should have been lower by 33 and drug crimes by 25 per 100,000 inhabitants. Generally, in the second level group the number of police officers was too high and the number of drug crimes exceeded expectations. The third spatial frontier consists of Belgium, Estonia, Hungary, Italy, Latvia, Lithuania, the Netherlands, Portugal, and Spain. Each is quite close to the second level – the farthest away being Italy, with overestimated inputs by 25% and in addition too many homicides by 20 per 100 000 inhabitants, while the closest was Lithuania with 5% inefficiency. These countries lie very far from the first level frontier – Italy's coefficient of 54% and Lithuania's of 66%. The main issue appears to be the high number of homicides, which needed additional adjusting by slacks. The fourth and last frontier encompassed the Czech Republic and the United Kingdom (UK), although they were less than 5% inefficiency from achieving the next upper level, while 40%-50% from the first level (see Table 3.).

Table 3. Context-Dependent DEA results for European states in 2003 by frontier level (efficiency coefficient and slacks for the closest upper lever frontier)

Frontier level	Country	Efficiency coefficient for upper level frontier [%]	Slacks					
			Expenditures on public safety [% of GDP]	Per 100 000 inhabitants				
				Police officers	Homicide	Violent crime	Theft of a motor vehicle	Drug trafficking
2	Bulgaria	44.4		42.6	3.7			3.74
	Cyprus	70		263.2			7.69	33.33
	France	90.6		102.6				83.33
	Germany	70.2						
	Greece	85.4		164.7			25	20
	Ireland	70		5.5				
	Slovakia	74.3			3.13	10	16.67	
	Slovenia	61.4						100
	Switzerland	94.1	0.11				33.33	25
3	Belgium	88.2		6.3	3.33			
	Estonia	84	0.27		1.28			
	Hungary	80			2.7			
	Italy	75.2			20			
	Latvia	89.9			1.33			
	Lithuania	94.5			2.04			
	Netherlands	91.2	0.03		5.26			
	Portugal	75.7		10.2	16.67			
	Spain	84.6		67.9	33.33			
4	Czech Rep.	94.30						
	UK	91.50	0.3		7.14			

Source: Own calculations based on STATA results. (Slack for outputs were inversed to the original form, they represent a suggested decrease in the number of crimes.)

4.2. Results for 2012

In 2012 the states were also in four frontier levels. There were ten countries with fully efficient public safety sectors: Finland, France, Hungary, Latvia, Norway, Poland, Romania, Slovakia, Slovenia, and Switzerland. The

second spatial frontier encompassed nine states: Austria, Bulgaria, Cyprus, Czech Republic, Denmark, Germany, Lithuania, Luxembourg, and Malta. Their effectiveness varied from 52% in Bulgaria to 97.3% in Denmark. In most countries, besides the proportional decline of inputs suggested by the efficiency coefficient, a supplementary correction of police officers by 10 – 136 people as well as the number of homicides by 1 – 10 per 100 000 inhabitants was possible. The third frontier encompassed Spain, Sweden, Estonia, Greece, Ireland, Italy, the Netherlands, Portugal, and UK, so also on 9 DMUs. The highest efficiency was observed in Greece, which wasted less than 3% of public safety inputs (29% compared to the first frontier), while the lowest registered was Spain with 47% of wasted resources (also 47% compared to the first frontier), which required an additional change of police force by 65 officers and homicides by 7 cases per 100,000 citizens. The problem with the number of police officers was less common on this level, but the number of homicides was still too high in relation to input-output combination. Moreover, a possibility of a further decline in public expenditures on public safety is visible, varying from 0.03% of the state's GDP in Ireland to 1.04% in the UK. The only country on the fourth and last frontier was Belgium, which was fairly close to the next upper level as the efficiency coefficient was equal to 93%, with a suggestion for an additional decline in the number of police officers by 101 and homicides by 7 per 100,000 Belgians. It is interesting that Belgium creates a one-state-level frontier, especially considering that it never was the least efficient country in comparison to any of the upper level spatial frontiers. Although its efficiency coefficient put Belgium among the most inefficient countries, in the case of the first level the value of 57% was actually slightly higher than in Bulgaria, Estonia, Italy, and Spain (see Table 4).

Table 4. Context-Dependent DEA results for European states in 2012 by frontier level (efficiency coefficient and slacks for the closest upper lever frontier)

Frontier level	Country	Efficiency coefficient for upper level frontier [%]	Slacks					
			Expenditures on public safety [% of GDP]	Per 100 000 inhabitants				
				Police officers	Homicide	Violent crime	Theft of a motor vehicle	Drug trafficking
2	Austria	83.4		66.5	1.79			
	Bulgaria	52			1.14			
	Cyprus	62.1		92.5				100
	Czech Rep.	72.5		70.3	2.27			
	Denmark	97.3		10.5	1.35			
	Germany	69.6		10.4	9.09			

	Lithuania	72			1.04			
	Luxembourg	89.3		136	10			
	Malta	88.1		104.7				
3	Spain	52.9		64.5	6.67			
	Sweden	77.5			3.45			
	Estonia	88	0.12		4.35			
	Greece	97.8						
	Ireland	76.8	0.03		33.33			
	Italy	61.8		0.06				
	Netherlands	84.2	0.54		50			
	Portugal	65						
	UK	91	1.04					
4	Belgium	93.4		100.9	6.67			

Source: Own calculations based on STATA results. (Slack for outputs were inversed to the original form, they represent the suggested decrease in the number of crimes.)

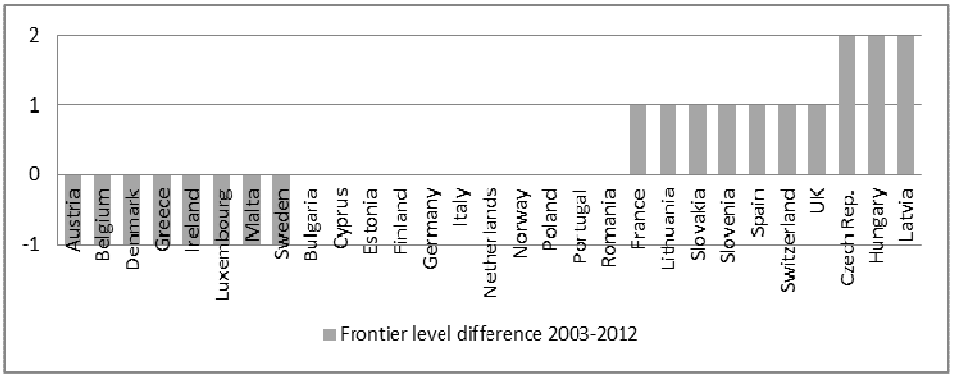
4.3. Comparison of 2003 and 2012

The conducted analysis allows for creating a spatio-temporal comparison of technical effectiveness of public safety sectors among the selected European states. Out of the 29 researched countries, eleven had a stable position between 2003 and 2012. Some, like Finland, Norway, Poland, and Romania maintained their leader status throughout the research, while others (Estonia, Italy, Netherland, and Portugal) were performing poorly. Eight countries dropped in position by one level: Austria, Denmark, Luxembourg, Malta, and Sweden, from the leader position in 2003 to the second frontier in 2012; Greece and Ireland from level 2 to 3; while Belgium fell from level 3 to the lone position on the fourth frontier. Meanwhile ten sates upgraded their efficiency. Slovakia, Slovenia, Switzerland, Hungary, and Latvia improved their public safety sectors and became leaders in 2012. The Czech Republic, Hungary, and Latvia achieved a major success by improving their efficiency by two levels.

Spatial distribution seemed rather random. In 2003 the Scandinavian countries clustered around the efficient public safety zone, however, this changed over time. Western and Southern Europe appeared to be rather inefficient in dealing with crime. In 2012 Central European countries, extending to the Balkans, were grouped as having highly effective public safety sectors.

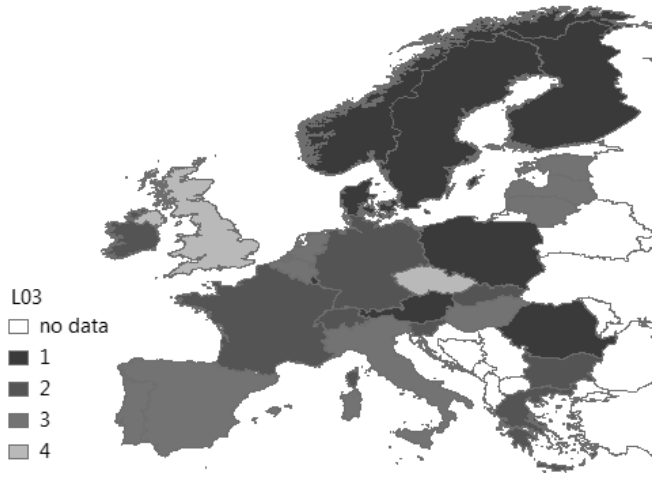
However, no international tendencies were visible. It appears that since the policy is design and carried out on a national level, the public safety sector is independent of any influence other than national. (see Figs.4,5,6).

Figure 4. Change in DEA frontier level in 2013 compare to 2003 in European states



Source: author's own.

Figure 5. Spatial distribution of Context-Dependent DEA level frontiers of European states in 2003



Source author's own in ArcMap.

Figure 6. Spatial distribution of Context-Dependent DEA level frontiers of European states in 2012

Source: author's own in ArcMap.

CD DEA results reveal some interesting facts. Firstly, it seems obvious that for inefficient states the smaller distance to a spatial frontier, the higher is the frontier's number. If a country is inefficient it should be easier to improve a little and achieve an upgrade by one level, say from frontier 3 onto 2, than jump to the first level in one round. In most instances this was the case. However, there were exceptions. Spain in 2012 was on the third level, but its inefficiency was almost the same as in the first and second frontier. This is unusual and true mostly for those countries with a low efficiency coefficient. What's more, DMUs located on the lowest frontier are not necessary the furthest from the first level. The relativity of the DEA approach means that the combination of selected DMUs influences the outcome.

The analysis results help to understand the main source of inefficiencies. Slacks that describe additional changes to the efficiency coefficient suggest that in most states the number of police officers is much too high compared to the number of crimes. Were there less people on the force, they would assure the same public safety, or at least this number of policemen should result in much lower crime rates. Moreover, there are too many homicides. Of course, in case of murders one is too many, but using a completely soulless and mathematical approach it may be said that these inputs should guarantee less homicides. It is interesting that different levels had different additional problems, which may partly reflect the source of the inefficiency and differentiation between frontier levels. What is more, the number of car thefts and persons convicted of drug trafficking, which was a major problem in 2003, did not generate any slacks in 2012.

5. Conclusions

Public safety is closely linked to both personal and public health, welfare, quality of life, and economic situation. Statistical analysis has shown that only the number of homicide declined in all but four states, while other crime rates in Europe increased in the last decade. This seems due to the severity of punishments and the crime detection rates concerning murder. For instance, in Poland in 2011 over 90% of homicide cases were solved, and only 22.5% of car thefts.(Statystyki ogólne Policji 2014)

Meanwhile public safety inputs varied across time and regions, being reduced in almost half of the researched countries. This does not draw an optimistic picture, as it suggests that Europe is becoming less and less safe. However, this does not indicate whether public safety systems are, or are not, effective. Clearly the lower the crime rates the higher the effectiveness. In most cases the minimal values of each crime group allows for a place on first level frontier. The highest values result in a decline of efficiency coefficients. Also the lower the inputs (expenditures and the number police officers) the higher the effectiveness. Less resources mean that they are better utilized. Overestimation of inputs does not bring about an additional reduction of crime.[1] However, it should be reminded that relative technical effectiveness does not reflect the "quality" of safety. One police officer and $1 will default to generate higher utilization rate than a thousand. The baseline for improvement is the frontier outdrawn by leaders (as in DEA approach) or at the very least the higher efficiency frontier.

Moreover, the DEA results show that there is no spatial regularity in public safety effectiveness. Neither the richer "old" nor poorer "new" EU states, nor their northern or southern, western or eastern locastions allow for any generalizations. Among the constant leaders were Finland, Norway, Poland, and Romania. Since they should be treated as benchmarks for other states, their economic and social policy diversity is an advantage. The inefficient countries have then a real choice which best performer to follow. This research proved as well that changes can be made and that they count, as the Czech Republic, Hungary, and Latvia succeeding in upgrading their efficiency level, measured by Context-Dependent (Stepwise improvement) spatial DEA approach, by two levels in less than ten years, which was especially noteworthy for Hungary and Latvia, as they advanced into the leading group.

[1] DEA approach perceives effectiveness as derived from the input-output combination. Although it can be argued that inputs influence effectiveness and effectiveness influences outputs.

Safety is definitely an important issue overall in Europe, and as crime rates tend to rise, choices and decisions need to be made to protect people and their property from danger, harm, or damage by increasing the technical effectiveness of the public safety sector. This can be achieved by acknowledging the existence of leaders and followers in this area and implementing a "learn-from-the-best" policy as an element of regional development.

References

Benson B.L., Zimmerman P.R (ed.) (2010) *Handbook on the Economics of Crime*, Edward Elgar Publishing.

Charnes A., Cooper W., Rhodes A. (1978), *Measuring the efficiency of decision making units*, 'European Journal of Operations Research'.

Eide E., Rubin P.H., Mehlop Shepherd J. (2006*), Economics of Crime*, Now Publishers Inc.

Eurostat Crime and criminal justice (crim) Reference Metadata in Euro SDMX Metadata Structure (ESMS) (http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/crim_esms.htm) (03.06.2014).

Compiling agency: Eurostat, the statistical office of the European Union.

Gospodarowicz, M. (2000), *Procedury analizy i oceny banków*. [in] Materiały i studia NBP zeszyt nr 103, Narodowy Bank Polski Departament Analiz i Badań, Warszawa, pp. 48-51; Golany B., Roll Y. (1989) Anapplication procedure for DEA. OMEGA Heft Vol. 17, pp. 240-247.

Galinienė B., Dzemydaitė G. (2012), *Spatial Data Envelopment Analysis Method for the Evaluation of Regional Infrastructure Disparities*, 'Social Technologies' 2012, 2(2), p. 390–403.

Gospodarowicz A. (2002), *Analiza i ocena banków oraz ich oddziałów*, Wydawnictwo Akademii Ekonomicznej im. Oskara Langego, Wrocław.

Kourtit K., Nijkamp P. (2013), *In search of creative champions in high-tech spaces: a spatial application of strategic performance management*, 'Journal of regional science', vol. 53, no. 5, 2013, pp. 749–777.

Ortmeier P. J. (1998), *Public Safety and Security Administration*, Gulf Professional Publishing.

Seiford L.M., and Zhu J. (2003), *Context-dependent Data Envelopment Analysis – Measuring attractiveness and progress*, Omega, 31, 2003, pp. 397-408.

Statystyki ogólne Policji: Postępowania wszczęte, przestępstwa stwierdzone i wykrywalność w latach 1999 – 2013 (2014) (http://statystyka.policja.pl/st/ogolne-statystyki/47682,Postepowania-wszczete-przestepstwa-stwierdzone-i-wykrywalnosc-w-latach-1999-2013.html) (04.05.2014).

Suzuki S., Nijkamp P. (2011), *A Stepwise Projection Data Envelopment Analysis for Public Transport Operations in Japan*, Tinbergen Institute Discussion Paper, TI 2011-113/3.

Streszczenie

LIDERZY I UCZNIOWIE EFEKTYWNOŚCI BEZPIECZEŃSTWA PUBLICZNEGO W KRAJACH EUROPEJSKICH – PRZESTRZENNA ANALIZA GRANICZNA

Bezpieczeństwo publiczne to ważny aspekt życia publicznego i prywatnego. Jednocześnie ze względów historycznych, kulturowych, społecznych, prawnych i finansowych jest ono jednym z najbardziej zróżnicowanych przestrzennie sektorów. W rezultacie utrudnione jest prowadzenie bezpośrednich analiz porównawczych polityk i funkcjonowania aparatu bezpieczeństwa publicznego. Jednak ocena i porównania są kluczowym elementem prowadzenia polityki „najlepszych praktyk" oraz „uczenia się od najlepszych" stanowiących ważny czynnik rozwoju regionalnego i globalizacji. Istnieją metody ilościowe jak DEA (Data Envelopment Analysis), które umożliwiają prowadzenie takich badań. DEA pozwala na analizę relatywnej efektywności technicznej w oparciu o regionalne nakłady i efekty bez konieczności uwzględniania specyfiki rozwiązań proceduralnych bezpieczeństwa publicznego poszczególnych krajów, traktując system jako nietypowy proces produkcyjny. Dlatego celem artykułu jest regionalna analiza efektywności technicznej systemu bezpieczeństwa publicznego w wybranych krajach europejskich oraz określenie przestrzennej granicy efektywności. W oparciu o uzyskane rezultaty badane kraje zostaną podzielone na dwie grupy – efektywną i nieefektywną. Państwa o efektywnych systemach uznawane są za „liderów" reprezentujących „najlepsze praktyki" , którzy powinni być traktowania jako wzorce dla obiektów nieefektywnych – „uczniów".

Nakładami w przeprowadzonym badaniu metodą DEA były nakłady finansowe oraz osobowe ponieważ są one kluczowe dla funkcjonowania systemu bezpieczeństwa publicznego. Efektami zaś były przekształcone liczby występowania głównych kategorii przestępstw. Analiza została dokonana dla lat 2003 i 2012. Uzyskane wyniki sugerują, że wśród liderów znalazły się Finlandia, Norwegia, Rumunia i Polska. Najniższą efektywność techniczną odnotowano dla Belgii, Wielkiej Brytanii, Estonii i Włoch, które nie wykorzystywały w pełni swoich nakładów. Przeprowadzone badania wskazuje, że pomimo wielu różnic w polityce bezpieczeństwa publicznego rozwój regionalny może być prowadzony poprzez implementacje podejścia „ucz się od najlepszych".

Słowa kluczowe: *analiza regionalna, bezpieczństwo publicane, ekonomika przestępczości, Data Envelopment Analysis (DEA)*