QUANTITATIVE METHODS IN ECONOMICS
Vol. XV, No. 2, 2014, pp. 339 – 348

TECHNICAL EFFICIENCY OF POLISH COMPANIES OPERATING IN THE COURIERS AND MESSENGERS SECTOR - THE APPLICATION OF DATA ENVELOPMENT ANALYSIS METHOD

Justyna Kozłowska
Department of Business, Informatics and Logistics
Bialystok University of Technology
e-mail: j.kozlowska@pb.edu.pl

Abstract: The main goal of this paper is an attempt to assess condition of polish couriers and messengers sector in terms of technical efficiency. The sector in Poland, in comparison to the Western Europe countries, is still under development. The research was conducted using Data Envelopment Analysis method, which is successfully applied worldwide both in public and private sector organizations. DEA allows to identify the best performers in analyzed group and build a ranking in terms of efficient resources utilization. Malmquist index was also calculated to assess changes in relative productivity over time and to detect which factors ("frontier shift" or "catch-up") affects them.

Keywords: couriers and messengers services, technical efficiency, DEA method, Malmqiust index

INTRODUCTION

First courier companies appeared in the polish market around the 1980s. Although the sector is relatively young, it plays a significant role in the national economy. Polish couriers and messengers market still dynamically develops, in comparison to the Western Europe countries, where the market has already stabilized. The use of courier services per capita is there a few times higher than in Poland, therefore the rapid growth will presumably continue in the near future. The main player in this market is public company – *Poczta Polska* (2,1 billion services provided in 2011), nevertheless the package segment is dominated by private operators (3,7 billion services provided in 2011) [Marcysiak at al. 2013] and the analysis presented hereof focuses on this group specifically. In the paper the

author made an attempt to assess the performance of companies operating in the mentioned above sector in terms of technical efficiency. Not only does the results of such analysis allow to identify entities which are the best in efficient utilization of its resources, and thereby indicate benchmarks for other players in the market, but also it can be the basis for further analysis of inefficient units and the first step to improve such entity's performance.

Efficiency, including technical efficiency, evaluation of any entity involves the study of its productivity [Kosieradzka A. 2000]. Productivity is define in literature generally as a single input-output ratio. However, more common problem pose analyses of multiple-input and multiple-output cases. The term "efficiency" is understood as a production without any wastefulness. Thus an economy (organization, company, unit etc.) is efficient when there is no way to increase a production of one commodity without a drop in production of another, what means it attains the production-possibility frontier or, in other words, achieves the highest level of production possibilities given the resources [Samuelson at al. 1995]. In this meaning, the term "technical efficiency" is also applied.

METHODOLOGY BACKGROUND

DEA method

Data Envelopment Analysis (DEA) is worldwide successfully applied method for evaluating the performance of a set of peer entities, in literature called "decision making units" (DMU), that transform multiple inputs into multiple outputs. DMU can operate in public (see studies of [Ruggiero J. 1996] or [Nazarko at al. 2008]) and private sectors (e.g. [Parlińska M. at al. 2008] and [Rangan N. 1988]), nonetheless a homogeneity of the units is a critical postulation. DEA was first introduce in 1978 by Charnes, Cooper and Rhodes as a Linear Programing based method and, since then, it has become a very popular means for productivity[1] assessment in academic research and in practice as a decision support tool for management level employees.

The basic DEA models enable to measure the efficiency of a DMU relative to similar DMUs in order to estimate a 'best practice' frontier [Cooper W. at al. 2004]. Primary DEA model is named CCR after its authors (Charnes, Cooper, Rhodes), assumes constant returns to scale, and is defined as follows (output-oriented model):

$$\max \; z = \sum_{j=1}^{J} v_{j,m} y_{j,m} \qquad (1)$$

subject to $\sum_{i=1}^{I} u_{i,m} x_{i,m} = 1$

[1]From this point, terms: productivity, efficiency and technical efficiency are alternatively used in the paper, however the author always means the efficiency in accordance to the DEA framework.

$$\sum_{j=1}^{J} v_{j,m} y_{j,m} - \sum_{i=1}^{I} u_{i,m}\, x_{i,m} \leq 0$$

$$u_{i,m}\,, v_{j,m} \geq 0$$

where:
z – weighted sum of outputs calculated for DMU_m (m=1,..,N);
$y_{j,m}$ – denotes DMU_m outputs (j=1,..,J);
$x_{i,m}$ – represents inputs (i=1,…,I) of DMU_m;
$u_{i,m}\,, v_{j,m}$ – weights that are unknown variables.

In input-oriented model the weighted sum of inputs of each DMU is minimalized and the level of its' inputs remains unchanged. In practice, a dual problem of (1) is solved. Primary model had several limitations (e.g. the assumption about returns to scale), thus many modification has been developed since its introduction. However, it is still regularly used in analyses of technical efficiency.

The standard DEA models allows to build a ranking of inefficient units, setting the best performers at the same level (of 100% efficiency). In 1993 Andersen and Petersen developed a new approach, the super-efficiency DEA (SE-DEA) model, which allows to rank DMU on the efficiency frontier [Andersen P. at al. 1993]. This innovation was a subject of many paper afterwards (e.g. [Thrall M.R. 1996], [Yao C. 2003] or [Zhu J. 2001]), and applied to real data researches (see [Helta M. 2009] or [Chen Y. 2004]). The basic idea of the new approach is to exclude the efficient DMU from the comparison set, so it cannot be compared against itself (which is the reason of receiving the score of 100% or 1), thus it can obtain score better or less than one in the input-oriented or output-oriented super-efficiency evaluation, respectively. The difference in the score is usually interpreted as an amount by which the DMU can exceed the performance if it peers.

It is highly desirable to differentiate units with the best results, as it can encourage them to improve theirs output and be better than others. Hence, this extension of DEA method was applied in the research presented hereof.

Malmquist index

Malmquist index represents a change in a unit's productivity over a period of time. In the non-parametric framework (as DEA method) it is defined as the product of two terms – a "frontier shift" (likewise technology change or innovation) term and a "catch-up" (also relative efficiency change or recovery) term. The first term represents changes in efficiency resulting from "industry" gains - i.e. the degree to which the surroundings has changed. The second term shows the degree to which the individual unit's efficiency has improved relative to the frontier - i.e. how far it as from the frontier at time t versus how far it was from the frontier at t+1. [Cooper W. et al. 2004]. Accordingly, Malmquist index (MI) is calculated with the following formula:

$$MI = \left[\frac{\delta^t((x_m,y_m)^{t+1})}{\delta^t((x_m,y_m)^t)} \times \frac{\delta^{t+1}((x_m,y_m)^{t+1})}{\delta^t((x_m,y_m)^t)}\right]^{1/2} \quad (2)$$

where:

$(x_m, y_m)^t$ denotes the vector of inputs (x_i, i=1,…,I) and output (y_j, j=1,…,J) of the DMU_m (m=1,..,N) in the period t,

$\delta^{t+1}((x_m, y_m)^t$ expresses the efficiency score of DMU_m measured by the frontier technology in the period $t+1$.

Malmquist index value of 1 signifies no change in total factor productivity, while values greater than 1 or less than 1 indicates the progress or regress, respectively.

It is essential for the productivity analysis to determine the index value as it allows to recognise the degree of efficiency changes, their direction and major factor ("catch-up" or "frontier shift") that affects them.

THE ANALYSIS AND ITS RESULTS

DEA model selection

Preliminary analysis with the CCR-DEA model indicated that the low score of few units' productivity were due to variable returns to scale, thus in the main research the BCC-DEA model was used. As the output in the service sector is rather difficult to control, the input-oriented model seemed to be more appropriate for this study. To build a ranking of all DMUs, the super-efficiency extension was applied.

Data and variables selection

Data for the analysis was collected from EMIS (Emerging Markets Information Service) database. The time period as well as the number of companies under examination were determined by the availability of the data at the first step. EMIS database gathers mainly financial data and reports so that the evaluation of technical efficiency covers an economic activity of the companies. Then Pearson correlation coefficient between variables were analyzed and variables with strongly linear dependence were chosen. As the author's intention was to obtain the results that can be used both for building general opinion about the sector and for practical reasons from entrepreneurs point of view, therefore following variables were finally chosen for further analysis: total assets and number of employees as inputs and total operating revenue as the output. The analysis was carried out for 23 largest companies from the sector. As the EMIS data are relatively new, the analysis covers the period of 3 years only: 2010, 2011 and 2012.

Table 1 presents values of Pearson correlation coefficient for selected variables.

Table 1. Pearson correlation coefficient values

	Operating revenue		
	2010	2011	2012
Number of employees	0,932236	0,935515	0,927888
Total assets	0,9016044	0,795428	0,754033

Source: own calculations

The league table

The table below presents the result of analysis conducted with Frontier Analyst Application software. It is organized in descending order, so the best performers in terms of technical efficiency are at the top of the table. *Polska Grupa Pocztowa S.A.* takes consistently the first place in every year of analyzed period. *UPS Scs (Polska) Sp z o.o.* takes the second position regularly. The third score received the *UPS Polska Sp. z o.o.*, but in the first two years of analyzed period only. In 2012 another unit appeared in the leading group, namely *World Courier (Poland) Sp. z o.o.*, which hitherto indicated inefficiency. Similarly, the *Madagra Sp. z o.o.* improved its output and joined the "best performers" group.

Table 2. Rankings built with the usage of super-efficiency DEA model

2010		2011		2012	
Unit name	Score	Unit name	Score	Unit name	Score
Polska Grupa Pocztowa S.A.	**413,90%**	**Polska Grupa Pocztowa S.A.**	**268,90%**	**Polska Grupa Pocztowa S.A.**	**321,20%**
Ups Scs (Polska) Sp. z o.o.	**128,50%**	**Ups Scs (Polska) Sp. z o.o.**	**170,60%**	**Ups Scs (Polska) Sp. z o.o.**	**205,60%**
UPS Polska Sp. z o.o.	**104,70%**	**UPS Polska Sp. z o.o.**	**120,30%**	**World Courier (Poland) Sp. z o.o**	**104,10%**
Transline Polska Sp. z o.o.	98,90%	Transline Polska Sp. z o.o.	94,70%	**Madagra Sp. z o.o.**	**103,20%**
Viva Xpress Logistics Polska Sp.	95,10%	Viva Xpress Logistics Polska Sp.	86,30%	UPS Polska Sp. z o.o.	83,90%
World Courier (Poland) Sp. z o.o	93,00%	Federal Express Poland Sp. z o.o	84,60%	Transline Polska Sp. z o.o.	82,10%

2010		2011		2012	
Unit name	Score	Unit name	Score	Unit name	Score
Federal Express Poland Sp. z o.o	88,20%	Madagra Sp. z o.o.	80,40%	Viva Xpress Logistics Polska Sp.	77,90%
Go! Express & Logistics Wrocław	68,90%	Money Save Polska Sp. z o.o.	72,00%	Federal Express Poland Sp. z o.o	75,20%
Fedex Express Polska Sp. z o.o.	67,40%	Go! Express & Logistics Wrocław	69,30%	TNT Express Worldwide Poland Sp.	65,60%
Patron Service Sp. z o.o.	64,90%	World Courier (Poland) Sp. z o.o	68,90%	Patron Service Sp. z o.o.	58,00%
Dpd Polska Sp. z o.o.	63,10%	Patron Service Sp. z o.o.	63,50%	Fedex Express Polska Sp. z o.o.	53,60%
Madagra Sp. z o.o.	62,70%	DHL Express (Poland) Sp. z o.o.	60,70%	DHL Express (Poland) Sp. z o.o.	52,20%
Riders Express Sp. z o.o.	55,70%	TNT Express Worldwide Poland Sp.	60,60%	Matmarex Sp J sp. j.	51,20%
DHL Express (Poland) Sp. z o.o.	55,30%	Riders Express Sp. z o.o.	59,80%	Money Save Polska Sp. z o.o.	46,30%
Money Save Polska Sp. z o.o.	47,60%	Fedex Express Polska Sp. z o.o.	57,50%	Riders Express Sp. z o.o.	44,30%
Matmarex Sp J sp. j.	47,10%	Matmarex Sp J sp. j.	56,60%	Go! Express & Logistics Wrocław	39,60%
Lande Sp. z o.o.	46,00%	Integer.pl S.A.	51,90%	Dpd Polska Sp. z o.o.	37,90%
TNT Express Worldwide Poland Sp.	45,00%	Dpd Polska Sp. z o.o.	44,70%	Integer.pl S.A.	37,70%
Siódemka S.A.	43,60%	Forposta S.A.	39,10%	Inpost Sp. z o.o.	32,80%
Trade System Sp. z o.o.	42,40%	Inpost Sp. z o.o.	36,30%	Lande Sp. z o.o.	32,70%
Inpost Sp. z o.o.	41,10%	Lande Sp. z o.o.	35,00%	Forposta S.A.	18,20%

2010		2011		2012	
Unit name	Score	Unit name	Score	Unit name	Score
Integer.pl S.A.	30,40%	Trade System Sp. z o.o.	24,10%	Siódemka S.A.	18,00%
Forposta S.A.	29,20%	Siódemka S.A.	12,60%	Trade System Sp. z o.o.	16,60%

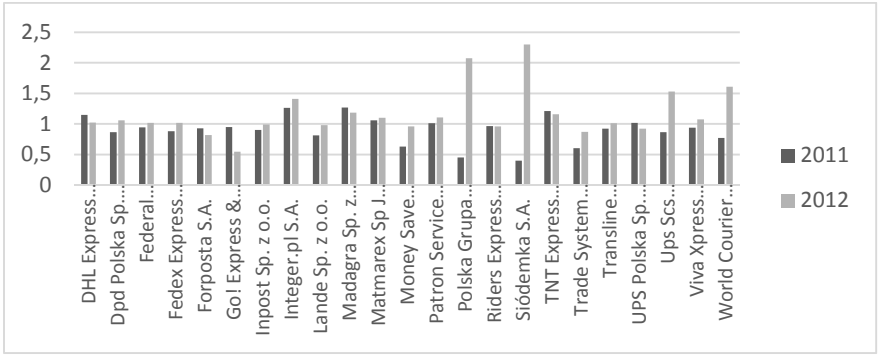
Source: own study based on *Frontier Analyst Application* software calculation

At the bottom of the table (the last few position) the same unit names appear every year, so one can conclude that those companies should reconsider the way they transform their inputs into effects. The minimum value of productivity scores is slightly above 10% in 2011 and 2012, whereas in 2010 it was close to 30%, which is rather alarming and worth to study in details. However, the average technical efficiency in analyzed period of time is around 60%, calculated using standard DEA model, and over 75% determined by supper-efficiency model, thus in general companies seem to manage their resources rather reasonably.

Changes of the efficiency in the 2010 - 2012

Figure 1 presents a magnitude of changes in productivity for each DMU in analyzed period of time. Most of the units (e.g. *DHL Express (Polska) Sp. z o.o*. or *Federal Express Poland Sp. z o.o*.) indicates sustainable changes in its productivity scores (around 1 e. i. without significant degree of change in both direction – up and down). Though, there are few entities (namely *Siódemka S.A.*, *Polska Grupa Pocztowa S.A.*, *World Courier Poland Sp. z o.o*.) which distinguish itself from the group with a very high value of Malmquist index in 2012 (MI >1,5).

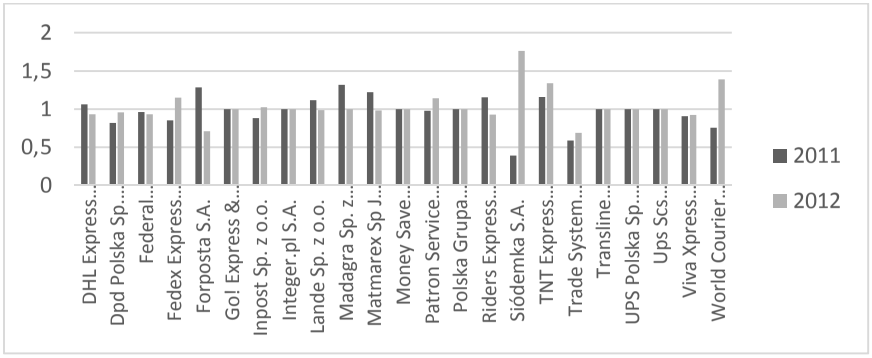
Figure 1. Malmquist index values for each DMU



Source: own calculations

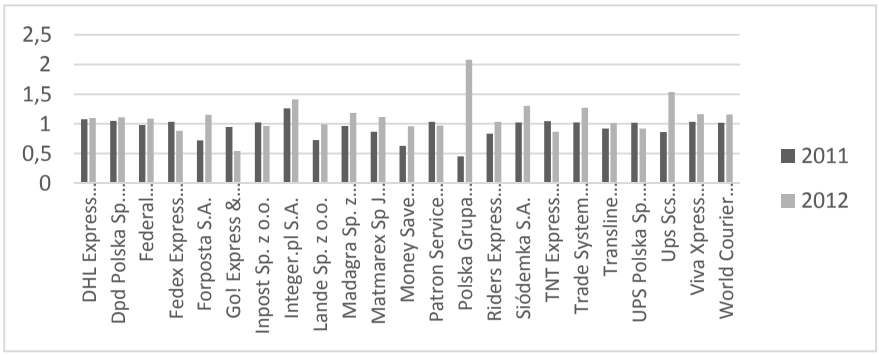
The study of the figures 2 and 3 reveals that these changes are affected mainly by the second term of the Malmquist index, e.i. a “frontier shift”. Moreover, the MI value of units in question was relatively low in the previous year, so presumably some inside issues impacted these units performance as well.

Figure 2. "Catch-up" for each unit – i.e. the relative efficiency change component



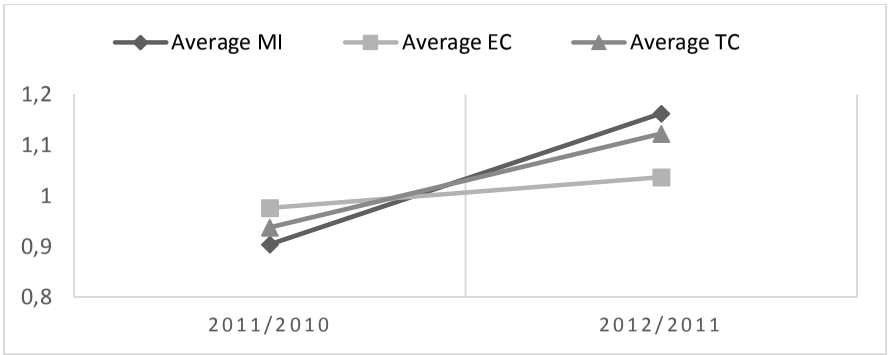
Source: own calculations

Figure 3. "Frontier shift" for each unit – i.e. technology change component (TC)



Source: own calculations

Figure 4. The average change of Malmquist Index and its components over analyzed period of time



Source: own calculations

Figures 2 and 3 show values of decomposed indices of the index for each unit. Every unit's Malmquist index can be greater than 1 even if one of its component decreases over time as long as the other component balances the difference. The average change of Malmquist index over the years 2010-2012 is 1,034, what means 3,4% overall increase of productivity in the group under evaluation, thus companies indicate an improvement of input-output ratio.

Figure 4 presents the average value of Malmquist index (MI) in 2011 (in reference to 2010) and 2012 (in reference to 2011) and its components at the time. Even though in 2011 there had been decrease of MI observed (its value was 0,904), the next year brought significant increase of the index (1,16 – i.e. average the index was 16% higher in comparison to 2011) therefore in general the input-output ratio in the sector has changed in positive way. The figure also shows the average change of decomposed indices and it suggests (as it was already mentioned above) that technology change term (TC) had greater impact on productivity changes in the sector in analyzed period of time than EC component.

SUMMARY

Couriers and messengers sector in Poland is relatively young, nevertheless its role in national economy is significant. The main player in this market is public company – Poczta Polska, however the package segment is dominated by private operators. Results of technical efficiency analysis conducted on 23 polish companies operating in the sector are presented hereof. The author intended to build a ranking of analyzed units in terms of productivity, therefore the DEA (Data Envelopment Analysis) method with super-efficiency extension was applied. The research allowed to identify the best performers in the analyzed period of time – the first two positions took consecutively *Polska Grupa Pocztowa S.A.* and *UPS Scs (Polska) Sp z o.o*. The third score received *UPS Polska Sp. z o.o.,* in the 2010 and 2011. In the last year (i.e. 2012) *World Courier (Poland) Sp. z o.o*. took the third position. The worst performers were: in 2010 - *Forposta S.A.*, in 2011 – *Siódemka S.A.*, and in 2012 - *Trade System Sp. z o.o*. The mean of scores in all analyzed period of time were over 60% and it suggests that couriers' companies rather reasonably utilize their resources. Malmquist index, which was also calculated for years 2010-2012, showed a 3,4% average increase in productivity of the group under evaluation and the main factor of these changes occurred to be the "frontier shift" component (technology change). In general the sector seems to indicate an improvement of the input-output ratio. The results of this study may be the basis for further analysis of the sector and of the specific DMU as well. The next step of the research can be also a recognition of best performers' strengths and worst performers' weaknesses, to indicate possible ways to enhance scores of efficiency in future.

REFFERENCES

A. Charnes, W. W. Cooper, and E. L. Rhodes (1978.), Measuring the efficiency of decision making units, European Journal of Operational Research, Vol. 2, pp. 429–444.

Andersen P., Petersen N.C. (1993), A procedure for ranking efficient units in data envelopment analysis, Management Science, Vol. 39, pp. 1261-1264.

Chen Y., Motiwalla L., Khan M. R. (2004), Using super-efficiency DEA to evaluate financial performance of E-business initiative in the retail industry, International Journal of Information Technology & Decision Making, Vol. 3, no. 2, pp. 337−351.

Cooper W.W., Seiford L.M., Zhu J. (2004), Handbook on data envelopment analysis, Kluwer Academic Publishers, Boston.

Helta M. (2009), Zastosowanie metody DEA do opracowania rankingu efektywności spółek Agencji Nieruchomości Rolnych w 2006 roku, Roczniki Nauk Rolniczych, seria G, Vol. 96-3, pp. 107-111.

Kosieradzka A.(2000), Ocena i analiza produktywności w przedsiębiorstwie [w:] Strategie wzrostu produktywności firmy, Science conference materials (red. A. Stabryła), Wydawnictwo Akademii Ekonomicznej w Krakowie, Kraków, pp. 284–293.

Marcysiak A., Pieniak-Lendzion K., Lendzion M. (2013) Usługi kurierskie na rynku usług logistycznych w Polsce, Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach, Seria: Administracja i Zarządzanie (23)2013, pp. 29-38.

Nazarko J., Komuda M., Kuźmicz K., Szubzda E., Urban J. (2008), Metoda DEA w badaniu efektywności instytucji sektora publicznego na przykładzie szkół wyższych, Badania operacyjne i decyzje 2008, Vol. 4, pp. 89-105.

Parlińska M., Bezat A. (2008), Efficiency of the polish wholesale markets . Validation based on the data envelopment analysis, Stowarzyszenie ekonomistów rolnictwa i agrobiznesu, Roczniki Naukowe tom X, Vol. 5, pp. 122-124.

Rangan N., Grabowski R., Y. Aly H., Pasturka C. (1988),The technical efficiency of US banks, Economy Letters, vol 28, Issue 2, pp. 169-185.

Ruggiero J. (1996), On the measurement of technical efficiency in the public sector, European Journal of Operational Research, Elsevier, Vol. 90, p.553–565.

Samuelson P., Nordhaus W. (1995): Ekonomia. T. 1. PWN, Warszawa, p. 185.

Thrall R.M. (1996), Duality, classification and slack in data envelopment analysis, Annals of Operational research, vol. 66, pp.109-138.

Yao C. (2003), Measuring super-efficiency in DEA in presence of infeasibility, European Journal of Operational research, vol. 161-2, pp.429–444.

Zhu J. (2001),Super-efficiency and DEA sensitivity analysis, European Journal of Operational Research, vol. 129, pp.443-455.