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Application of selected statistical methods to ICT used in Public Procurement System in Poland

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Streszczenie: W niniejszej pracy podjęta zostanie próba wielowymiarowej analizy rozwoju elektronicznych zamówień publicznych oraz jego determinant w oparciu o dane pochodzące z wywiadów kwestionariuszowych, przeprowadzonych wśród podmiotów zamawiających, zobligowanych do stosowania Pzp. Będzie mieć miejsce testowanie wybranych metod statystycznych dla potrzeb pomiaru, klasyfikacji i analizy determinant rozwoju elektronicznych zamówień publicznych.

Słowa kluczowe: zamówienia publiczne, regresja logistyczna

INTRODUCTION

Public procurement is a necessary element of economies functioning in every part of the world. The public procurement market in the European Union is estimated at 16% of GDP [EIM 2004] and the market's value in Poland in 2008 stood at 109.5 billion zlotys, i.e. 8.6% of Polish GDP [*Sprawozdanie* … , 2009], which suggests that the Polish public procurement market has only started to grow. In the next few years, it can be expected to expand faster, following a wider use of public aid co-financed by the EU funds. Therefore, instruments need to be implemented that could improve the effectiveness of public procurement systems and give a more important role to the SMEs. A broader use of ICT tools in public procurement, especially the computerization of its procedures, seems a good and relevant way forward.

The paper performs a multivariate statistical analysis of e-procurement development and of its determinants using data derived from surveys of the awarding entities covered by the Public Procurement Law. Statistical methods were especially applied in order to measure, classify and model the development of ICT-based public procurement.

COMPUTERIZATION OF PUBLIC PROCUREMENT PROCESSES IN EU – MAJOR TRENDS

Modernization of the public procurement market and its better availability may become a key factor strengthening European Union's competitiveness and providing enterprises with new opportunities, especially the SMEs. Improved competitiveness and efficiency of enterprises operating in the public procurement area that stem, among other things, from the development of e-procurement are likely to influence the whole economy and play an important role in achieving the goals of the Lisbon Strategy. New ICT techniques applied to purchase goods and services make competition stronger and public purchasing more efficient, especially in terms of time and financial savings. It is estimated that e-procurement may help the awarding entity and the economic operators to save as much as 5% of their expenses and up to 50-80% of transaction costs [Ramboll M. 2004]. Previous years' experiences show that an awarding entity using e-procurement procedures may save even 10-20% compared with one applying the traditional methods. It is so, because entrepreneurs operating IT procedures can offer better prices, while in a traditional system their offers are final [Wikariak 2009].

In 2006, 71% of the Member States already had functional ICT-based public procurement systems, while the remaining 29% were in the process of developing them. Poland belonged to the second group. Among the European forerunners of e-procurement systems there are Italy and UK. However, the implementation of e-procurement instruments does not necessarily mean that they are used more widely. A case in point is the electronic mode of tendering (Prince, Zeiden 2004]. Studies conducted by GHK and Technopolis have revealed that e-procurement is not common in Europe: 58% of the surveyed companies have never submitted fully electronic tenders and 43% have not done that even partly. The proportion of companies submitting fully electronic tenders 'at least sometimes' is only 24%. However, there are large variations between particular Member States. The leaders in the area are the UK and Lithuania, where 62% and 69% of companies, respectively, claim to submit electronic tenders at least sometimes. Finland, Denmark and Sweden also score well. The lowest percentages of such enterprises have been found in France, Malta, Hungary and Poland (3%). Similar findings have been provided by the studies discussed in the next sections of the paper [GHK&Technopolis 2007].

COMPUTERIZATION OF PUBLIC PROCUREMENT PROCESSES IN POLAND – APPLICATION OF SELECTED STATISTICAL METHODS

THE METHODOLOGY FOR QUANTIFYING IT DEVELOPMENT IN PUBLIC PROCUREMENT

It is difficult to evaluate the development of e-procurement because of insufficient informational resources. The statistics provided by the Public Procurement Office (PPO) only include information on the number of tenders involving electronic bidding and the Dynamic Purchasing System (DPS). In 2006, electronic bidding accounted for only 0.3% of all awarded contracts, with the rate falling to 0.05% in 2007 and 2008 and then rising to 0.11% in first quarter 2009. The Dynamic Purchasing System is not very popular either – in 2007 DPS was not used at all, in 2008 there were 10 DPS-based tenders, but in the first quarter of 2009, only one announcement of this type was made. Data on other e-procurement instruments are not available [BI UZP 2008, 2009]. This kind of information can be usually acquired in the course of field research. Unfortunately, most of the data provided during interviews and surveys (e.g. electronic) are confidential, which prevents the use of more advanced analytical methods. This fact inspired us to try to construct a synthetic indicator of the development level of public e-procurement (based on discrete variables).

The selection of diagnostic variables is one of the most important and also most difficult issues in constructing synthetic variables. Variables are generally selected using two approaches: one considering variable relevance and one statistical. An overview of the Polish solutions and studies requested by the European Commission suggests that the diagnostic variables should be enhanced with factors given in Table 1. The list is certainly not exhaustive, but it indicates e-procurement instruments and procedures that are currently used in Poland.

Each of the variables is binary (1 meaning that the respondent is knowledgeable of public e-procurement procedures). The obtained synthetic indicator representing a sum of all diagnostic variables and thus measuring the level of computerization of a public procurement system (synt) took values between 0 and 19 points. The higher the indicator's value, the more advanced e-procedures of a public procurement system.

The constructed indicator will be used to break down the awarding entities into two groups:

Gr. 1 – organizations with an insufficient level of e-procurement development (the indicator's values are up to 9 points),

Gr. 2 – organizations with a sufficient level of e-procurement development (the indicator's values range from 10 to 19 points).

An alternative to the above approach is classifying the awarding entities using cluster analysis. Our study will test both the procedures.

Table 1. List of potential diagnostic variables (questionnaire questions)

Symbol	Variable (question)
X_1	Did you know that the Public Procurement Office (PPO) had the web portal www.portaluzp.gov.pl?
X_2	Did you know that the PPO had the website – www.uzp.gov.pl?
X_3	Are you aware of the availability of the Internet bulletin TED?
X_4	Do you use the web portal www.portaluzp.gov.pl?
X_5	Do you use the website at www.uzp.gov.pl?
X_6	Does your organization use software that supports the awarding of contracts?
X_7	Does your organization have a buyer profile?
X_8	Does your organization use electronic means of transferring statements, requests, notifications and information related to contract awarding?
X_9	Do you think that the PPL obligates the awarding entity to specify the essential terms of contract on the website for bidding other than unlimited bidding?
X_{10}	Does your organization publish such specifications on the website for bidding other than unlimited bidding?
X_{11}	Do you think the PPL allows submitting tenders electronically, if approved by the awarding entity?
X_{12}	Do such tenders need to have a secure electronic signature that is verifiable using a valid qualified certificate?
X_{13}	Does your organization accept electronic tenders bearing a secure electronic signature that is verifiable using a valid qualified certificate to award contracts?
X_{14}	Do you know the electronic bidding scenario laid out in PPL regulations?
X_{15}	Has your organization ever used electronic bidding that the previous PPL regulations called an electronic auction?
X_{16}	Do you know the electronic auction scenario defined by the current PPL regulations?
X_{17}	Has your organization ever participated in an electronic auction?
X_{18}	Do you know the dynamic purchasing system scenario (DPS) provided in the PPL regulations?
X_{19}	Has your organization ever used the dynamic purchasing system scenario?

Source: own study.

MULTIVARIATE STATISTICAL METHODS IN THE EVALUATION OF E-PROCUREMENT DEVELOPMENT

The development of e-procurement in Poland has been analyzed using mainly the multivariate methods. The multivariate analysis allows dealing with many variables at the same time. Among the methods used by the analysis, the most useful seem to be cluster analysis (to classify the tenderers) and logistic regression (to model the development of e-procurement).

In the *logistic regression models***,** the dependent variable is dichotomous and its value is 1 when the probability of success is θ, or 0 when the probability of failure is 1-θ. A logistic regression model examines the relationship between one or more independent variable (called risk factors) and the log odds of binary outcome variable. This relation is described by the formula:

$$P(Y=1) = \frac{1}{1+\exp(-(B_0 + B_1 \cdot x_1 + \ldots + B_k \cdot x_k))} \quad (1)$$

where x_1, x_2, ..., x_k are independent variables (continuous or categorical). Odds ratios are commonly employed to measure the strength of the partial relationship between one predictor and the dependent variable (in the context of the other predictor variables). A model is constructed based on an iterative maximum likelihood procedure [Wuensche 2007].

Cluster analysis is an exploratory data analysis tool that aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise [Larose 2006, p.151]. A typical approach to cluster analysis first compiles a table of relative similarities or differences between all objects and then uses this information to put objects into groups. The table of relative similarities is called a proximities matrix. The method of combining objects into groups is called a clustering algorithm. The aim is to combine similar objects into separate groups. After identifying the inter-object distances, the next procedure of cluster analysis divides the objects into groups according to the distances (one possibility being the squared Euclidian distance). This is sum across variables (where $i = 1, \ldots, v$) of the squared difference between the score on variable i for the one case (X_i) and the score on variable i for the other case (Y_i). Following that, all the distances between the entities (cases and clusters) are recomputed and then two entities separated by the smallest distance are grouped together. When one of the entities is a cluster, or both, the averaged squared Euclidian distance between the members of both entities is computed. This procedure continues until all cases are formed into one giant cluster. It is for the researcher to decide when the procedure should stop and to accept a solution having k clusters (where $k = 1, \ldots, N$) [Walesiak, Gatnar 2009, pp. 407-420].

EMPIRICAL RESULTS

Between January and May 2008, an empirical survey requested by the Public Procurement Office (PPO) was conducted. It aimed at evaluating the status quo and the prospects for public procurement computerization in Poland (the survey's results are presented in detail in [Borowicz 2008]). The survey was designed to investigate the use of broadly understood ICT tools in public procurement. This paper presents the results of interviews conducted with a representative, random sample of 701 awarding entities. Because the questionnaire used in the survey catered

for PPO's informational needs, this fact largely narrowed the range of statistical methods that could be applied to analyze respondents' answers. Therefore, most variables represent nominal-scale measures. Moreover, the paper presents the results of multi-dimensional analysis of e-procurement development. Methods enabling the synthetic evaluation of e-procurement development (by constructing a synthetic indicator to evaluate the level of computerization in the surveyed entities) as well as classification of entities by the level of sophistication of their e-procurement systems (using the constructed indicator and cluster analysis) will be thoroughly tested. Besides, an attempt is being made to identify the determinants of e-procurement system development in the awarding entities (using logistic regression).

Because of the practical purpose of the conducted survey (it aimed at identifying the causes of the very weak interest in electronic procedures as well as actions that could curb unfavourable trends), most of its questions requested respondents' opinions on electronic PP procedures, so using them to construct the indicator was pointless. Unfortunately, the limited number of potential variables in the survey and the nominal level of their measurement prevented us from using most formal methods of variable selection. Consequently, the variables were selected using the substantial approach and the indicator of ICT development in public procurement was constructed using all potential diagnostic variables (Table 1). All calculations were run based on the SPSS 14.0 software.

The empirical investigation showed that the surveyed organizations had relatively good knowledge of the electronic instruments used in public procurement – especially of the PPO's web portal and website that the awarding entities use willingly. However, the possibility of submitting tenders electronically apart, the practical use of other instruments is insufficient and even insignificant in the case of electronic bidding, electronic auctioning and Dynamic Purchasing System (despite their being known well). Consequently, the overall evaluation of ICT level in public procurement is not very high.

The level of ICT used by the awarding entities seems to be mediocre as measured by the synthetic indicator (both $\bar{x}$ and Me are close to 9 against the maximum score being 19) – the index values for the sample range from 3 to 15 points. It is noteworthy that the distribution of the constructed variable is 'stabilized' (low skewness and kurtosis of distribution), which is confirmed by the analysis of normality plot and box-plot. This justifies the application of the parametric methods of analysis. The constructed indicator's reliability is relatively high (α=0.560), but the performed factor analysis indicates that mid-scales can be distinguished. Because of the limited number of factors, the next part of the analysis uses an indicator that has been constructed in line with the presented procedure. An additional argument in favour of this approach is high compatibility of awarding entities' classifications based on the synthetic variable and on the cluster analysis (Table 2).

Both the methods (using the same list of diagnostic variables/items) produced similar classifications of awarding entities as far as the computerization of public procurement is concerned. The value of Kappa Cohen's consistency ratio confirms the both the classifications are very much alike (κ=0.744 with p close to 0).

Table 2. The similarity of classification of the awarding entities performed using the synthetic indicator and cluster analysis with respect to the development of e-procurement

			clusters		Total
			unsufficient	sufficient	
synt_gr	unsufficient development	Number	205	24	229
		%	88.7	14.2	57.3
	sufficient development	Number	26	145	171
		%	11.3	85.8	42.8
Total		Number	231	169	400
		%	100.0	100.0	100.0

Source: own calculations.

The development of electronic procedures within public procurement is driven by many factors – administrative, legislative, economic and psychological. The scope of the questionnaire surveys prevents a correspondingly broad analysis. The main barriers as indicated by the respondents are too complicated regulations laid out in the PPL and the related laws, as well as professional and practical training in this field falling short of the actual needs [Wiktorowicz, Roszko-Grzegorek 2009]. The presented analysis aims to identify factors that have an effect on the development of e-procedures in public procurement. The development of ICT tools in public procurement will be evaluated by means of logistic regression analysis – separately for two dependent variables: *synt_gr* (formed by dividing *synt* variable variants into two classes, ie. Gr. 1 and Gr. 2) and a cluster (resulting from the classification provided by cluster analysis). The multi-dimensional analysis of relations was carried out by distributing the factors among three groups, i.e.:
(1) factors related to the awarding entity's location (Table 4): *REG* – region by GDP (economic development – ED), *SIZE* – the size of the urban area;
(2) major characteristics of the awarding entity (Table 5): *N* – the number of contracts awarded in 2007 (between the thresholds requiring mandatory PPL application in Poland and in the EU), *L* – the number of employees working in the public procurement department, *TYPE* – the type of the awarding entity;
(3) respondents' characteristics (Table 6): *IT* – IT skills, *EXP* - professional experience in public procurement, *EDU* – level of education.

We expected e-procurement to be the best developed in awarding entities that initiate large-scale public procurement procedures more often, based in regions at a higher level of economic development (such as Mazowieckie or Slaskie), especially in large urban areas. A more common use of ICT in public procurement

could be facilitated by high skills of employees. The results of the applied modelling procedure proved that our expectations were right (see Tables 3-6).

Table 3. Estimation results of the logistic regression equation parameters (eq. 1a i 1b)

Independent variables	Dependent variable							
	synt_gr (1a)				*clusters* (1b)			
	B	Wald	p	Exp(B)	B	Wald	p	Exp(B)
REG		4.719	0.094			1.129	0.569	
high ED	0.584	4.259	0.039	1.793	0.269	0.916	0.339	1.309
medium ED	0.233	0.701	0.403	1.263	0.071	0.066	0.797	1.074
SIZE		7.367	0.025			6.428	0.040	
country	-	5.284	0.022	0.368	-1.067	6.379	0.012	0.344
small-or medium-	-	0.008	0.928	0.974	-0.384	1.681	0.195	0.681
Constant	-	2.248	0.134	0.580	-0.048	0.018	0.894	0.953

* Reference group: for *RG* – region with low economic development, for *SIZE* – large urban areas
Source: own calculations.

The estimates of models 1a) and 1b) provided in Table 3 show that the size o the urban area where the awarding entity is located significantly influences the evaluation of ICT used by the entity in the public procurement area. In organizations located outside large urban areas the use of ICT is much more limited (p=0.022 for model 1a) and p=0.012 for model 1b)), with deflection reaching as much as 65%. The level of economic development in the awarding entity's district does not exert a statistically significant influence, but a comparison of models 1a) and 1b) reveals significant deflections between organizations based in the well-developed regions and in the less successful ones (p=0.039). Notwithstanding, both models show, as expected, that in the richer regions the odds of organization's achieving a higher level of computerization are larger (about 30-80% depending on the model) compared with the reference group.

Table 4. Estimation results of the logistic regression equation parameters (eq. 2a and 2b)

Independent variables	Dependent							
	synt_gr (2a)				*clusters* (2b)			
	B	Wald	p	Exp(B)	B	Wald	p	Exp(B)
N	0.026	12.766	0.000	1.026	0.018	7.610	0.006	1.018
L		4.102	0.251			0.550	0.908	
1 person	-20.624	0.000	0.999	0.000	-20.700	0.000	0.999	0.000
2 – 5 persons	-20.185	0.000	0.999	0.000	-20.653	0.000	0.999	0.000
6 – 10 persons	-20.077	0.000	0.999	0.000	-20.238	0.000	0.999	0.000
TYPE		7.292	0.063			10.970	0.012	
ZOZ	0.468	0.875	0.350	1.597	0.311	0.419	0.518	1.364
government	0.541	1.128	0.288	1.718	0.904	2.984	0.084	2.471
others	-0.373	1.831	0.176	0.688	-0.443	2.680	0.102	0.642
Constant	19.975	0.000	0.999	0,004	20.336	0.000	0.999	0,007

* Reference group: for *L* – over 10 persons, for *TYPE* – local administration
Source: own calculations.

As shown by data presented in Table 4, organization's involvement in public procurement activities as measured by the number of tenders is important. Organization's chances of developing e-procurement tools are determined quite strongly by its type, but local administration is not statistically significantly different from the reference group (particularly high and positive differences are noted for the central government administration). Compared with other factors, such as the aforementioned number of tenders and the type of organization, the rate of employment proved to be insignificant (*p* is close to 1).

Interesting conclusions can be drawn from the analysis of results presented in Table 5. A comparison of the previous equations shows that ICT development in the organizations is mainly decided by the human factor and not by solutions provided within the PPL. Organizations with experienced and well-educated staff are more likely to develop IT solutions in the public procurement area.

Table 5. Estimation results of the logistic regression equation parameters (eq. 3a i 3b)

Variables	Dependent							
	synt_gr (3a)				*clusters* (3b)			
Indendent	B	Wald	p	Exp(B)	B	Wald	p	Exp(B)
IT		6.195	0.103			3.979	0.264	
low	-0.955	4.108	0.043	0.142	-1.039	1.346	0.246	0.354
medium	-0.500	0.667	0.414	0.607	-0.308	0.242	0.623	0.735
high	-0.206	0.109	0.741	0.814	0.045	0.005	0.943	1.046
EXP		12.804	0.005			16.911	0.001	
below 1 year	-0.259	7.212	0.007	0.284	-1.548	9.300	0.002	0.213
1 – 2 years	-0.818	3.689	0.055	0.441	-0.437	1.163	0.281	0.646
2 - 5 years	-0.579	5.887	0.015	0.560	-0.801	10.592	0.001	0.449
EDU		5.795	0.215			10.661	0.031	
secondary or lower	-0.128	5.368	0.021	0.324	-1.338	7.055	0.008	0.262
incomplete tertiary	-0.028	3.429	0.064	0.358	-1.087	3.657	0.056	0.337
undergraduate	-0.678	1.555	0.212	0.508	-0.400	0.505	0.477	0.670
graduate	-0.856	3.737	0.053	0.425	-1.145	6.225	0.013	0.318
Constant	1.261	2.998	0.083	3.530	1.300	3.026	0.082	3.669

* Reference group: for *IT* – very high, for *EXP* – over 5 years; for *EDU* - doctorate/ PP postgraduate
Source: own calculations.

The analysis is completed with equations that were built using all variables from the list of potential factors (Table 6). The estimates were similar for both response variables: unlike the other factors, the type of awarding entities, the number of the awarded contracts and employees experience in PP activity proved significant. The only difference between versions (a) and (b) is the location of the awarding entity – both regions (4a model) and the size of the urban area (4b model) turned out to be important. Therefore, the characteristics are analogous to those presented in models 1-3.

Table 6. Estimation results of the logistic regression equation parameters (eq. 4a and 4b)

Dependent: *synt_gr* (4a)					Dependent: *clusters* (4b)				
Model 4a	B	Wald	p	Exp(B	Model 4b	B	Wald	p	Exp(B)
REG		7.792	0.020	2.233	*SIZE*		8.038	0.018	
high ED	0.803	7.261	0.007	1.454	country	1.289	7.579	0.006	0.275
medium ED	0.374	1.528	0.216	1.029	small- and medium-	0.694	4.775	0.029	0.500
N	0.028	15.749	0.000	1.809	*N*	0.01	8.031	0.005	1.018
TYPE		8.199	0.042		*TYPE*		13.142	0.004	
ZOZ	0.593	1.350	0.245	1.610	ZOZ	0.22	0.208	0.648	1.256
government administra-	0.476	0.827	0.363	0.660	government administra-	0.571	1.067	0.302	1.771
others	-0.415	2.189	0.139		others	0.700	5.770	0.016	0.496
EXP		8.536	0.036		*EXP*		13.209	0.004	
below 1 year	-0.957	4.241	0.039	0.384	below 1	1.219	5.945	0.015	0.296
1 – 2 years	-0.548	1.522	0.217	0.578	1 – 2 years	0.122	0.083	0.773	0.885
2 - 5 years	-0.573	5.223	0.022	0.564	2 - 5 years	0.770	9.070	0.003	0.463
Constant	-0.639	3.433	0.064	0.528	Constant	0.86	3.927	0.048	2.375

* See symbols in Tables 4-7

Source: own calculations.

CONCLUSION AND FUTURE RESEARCHES

The procedures of multi-dimensional statistical analysis are only partly useful in examining the survey's results, because of the nominal level of measurement of the investigated phenomena. The measurement methodology proposed in this paper allows comprehensive evaluation of computerization processes in public procurement. The use of logistic regression made it possible to identify certain factors determining progress in the area of e-procurement. Compared with other factors, the type of the awarding entity and its location, as well as the number of awarded contracts and employees' experience in PP turned out significant. Awarding entities based in cities have the best-developed e-procurement facilities, especially local government units and Public Healthcare Establishments. Their involvement in public procurement activity as measured by the number of awarded contracts and the number of PP-dedicated personnel is relatively high. They can develop ICT solutions more intensively because their staff is supported by skilled IT specialists, employees dealing with public procurement are trained to upgrade their ICT skills and large-scale informational campaigns on e-procedures are more readily available.

The development of e-procurement may be a factor boosting innovativeness – in both enterprises competing for contracts and in the awarding entities. Our future research will investigate how public procurement influences innovation activities in enterprises, especially in the SMEs. We will continue our efforts to test the development of e-procurement using statistical methods.

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Application of selected statistical methods to ICT use in the Public Procurement System in Poland

Abstract: The paper discusses the application of multivariate analysis tools to the development of e-procurement and to the determinants of the process using data derived from a survey of the awarding entities. In particular, statistical methods were used to measure, classify and model the development of computerized public procurement.

Keywords: public procurement, logistic regression