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Transaction Costs in PPP Transport Infrastructure Projects:

Comparing Procurement Procedures

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Empirical evidence: NonParametric procedures

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EMPIRICAL EVIDENCE USING NONPARAMETRIC PROCEDURES

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1. Methodology

In the previous section, we have carried out parametric tests to obtain evidence regarding the significance of the key variables of our model.

In order to proceed so, the strong condition on the data was that the population from which the data were collected followed a tipically normal distribution.

When normality condition is met, researchers resort to parametric procedures because they are more precise, accurate and reliable. Nonetheless, when doubts arise about the distribution of the population, researchers have the option to use nonparametric procedures. Therefore, nonparametrics is regarded when the normal distribution condition is not clearly met or do not require the data to have a specific distribuition.

In our model, our data follow a normal distribution; we are confident about meeting the normality condition. Notwithstanding, given that we are aware of working with small sample data sets, for both the private and the public sector but particularly for the latter, we are now extending the analysis to nonparametric statistics.

In this context of uncertainty regarding the conditions for applying parametric statistics, carrying out nonparametric tests will help us double check our previous outcome and eliminate the doubts and concerns of making wrongheaded assumptions or drawing wrong conclusions.

We are conducting a Kruskal- Wallis test as the nonparametric equivalent to a parametric analysis of Variance (ANOVA). Kruskal-Wallis compares the medians of more than two populations to see whether or not they are different and hence, to see whether all samples come or not from identical populations.

The null hypothesis for the Kruskal-Wallis test is:

H_0: all k samples have the same median (therefore, they come from identical populations)

While the alternative hypothesis for the Kruskal-Wallis test is:

H_1: the median of at least one of the k samples is different (at least one sample comes from a different population)

To test these hypotheses, the Kruskal-Wallis test statistic is H:

$H= 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

n_i represents the number of observations of one of the k samples

k is the number of samples we are comparing (two or more samples)

R_i is the rank sum in sample i

The Kruskal-Wallis test statistic (H) is compared to the Chi-square distribution with (k-1) degrees of freedom at a significance level equals to α= 0.05.

If H is greater than the Chi-square critical with (k-1) degrees of freedom at a significance level of α = 0.05, there is evidence to reject the null hypothesis.

H> X^2 ***(k-1), (1-α)***

If so, we then conclude that the populations (samples) have different medians or locations. We do accept the alternative hypothesis.
When a set of samples do not share the same median and the Kruskal-wallis test has rejected the null hypothesis, we will then use the Wilcoxon rank sum test.

All in all, the ultimate goal of our study is to identify which variable of our model is significant in determining the level of transaction costs for both the private and the public sector. The Kruskal-wallis test and the Wilcoxon rank sum test will help us determine which variable is significant for our assumptions on transaction costs.

In section 2 we detail the outcome of the nonparametric tests. Section 3 will draw the main conclusions of the nonparametric procedures. The annex, section 4, will present the tables with nonparametric results.

2. Results of applying nonparametric statistics

While resorting to nonparametric tests to analyse the data we are seeking the significance of the different determinants of transaction costs for both sectors. We have used two nonparametric tests, the Kruskal-Wallis test and the Wilcoxon rank sum test, to assess the impact of every determinant or variable on transaction costs, while others remain constant.

Both methods allow us to compare two populations of data, where random samples taken form each population are independent.

The Kruskal-Wallis test has been conducted for the private and the public sector samples. The Wilcoxon rank sum test is run only for the variable " procurement procedure" for both samples, private and public. Only when the Kruskal-wallis test has rejected the null hypothesis, we have conducted the Wilcoxon rank sum test.

The methodology has been the same for both samples. Firstly, we have determined our Hypotheses:

- The null hypothesis for the Kruskal-Wallis test:

  H_0: all k samples have the same median (therefore, they come from identical populations)

  While

- The alternative hypothesis for the Kruskal-Wallis test:

  H_1: the median of at least one of the k sample is different (at least one sample comes from a different population)

Secondly, after determining the Hypotheses, we have taken the following steps to carry out the Kruskal-wallis test:

We have ranked each observation from the smallest to the largest (using all samples combined). Afterwards we have obtained the rank sums for each of the samples; R_i, where i=1,2…k.

We have calculated the H test statistic, where N is the total number of observations (all sample sizes combined). We then have compared the H to the Chi-square distribution with k-1 degrees of freedom at a significance level and have made a conclusion whether the null hypothesis can or cannot be rejected.

If H is greater than the Chi-square critical with (k-1) degrees of freedom at a significance level of α = 0.05, there is evidence to reject the null hypothesis.

H> X^2 ***(k-1), (1-α)***

(See annex)

a. *Nonparametric results for the public sector*

i. *Kruskal-wallis tests*

- Kruskal-wallis test for type of infrastructure

We have two samples representing two different types of Infrastructure: Roads and Railways

$H = 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=18, number of observations

n_i represents the number of observations of one of the k samples

n1=12(road projects)

n2=6 (railway projects)

k is the number of samples we are comparing (two samples)

R_i is the rank sum in sample i

H< X^2 ***(k-1), (1-α)***

Since H is smaller than the Chi-square critical with 1 degree of freedom at a significance level of α = 0.05, there is evidence ***to accept the null hypothesis***. Therefore, we may conclude that samples have the same median or location. That is to say, for the public sector sample, the type of infrastructure is NOT a significant variable in determining the level of transaction costs.

- Kruskal-wallis test for procurement procedure

We have two samples depending on the bidding procedure: Negotiated Procedure and Open Procedure

$H = 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=18, number of observations

n_i represents the number of observations of one of the k samples

n1=8 (negotiated procedure projects)

n2=10 (open procedure projects)

k is the number of samples we are comparing (two samples)

R_i is the rank sum in sample i

H> X^2 (k-1), (1-α)

Since H is greater than the Chi-square critical with 1 degree of freedom at a significance level of $\alpha = 0.05$, there is evidence ***to reject the null hypothesis***. Therefore, we may conclude that samples have different medians or locations. That is to say, the procurement procedure IS a significant variable in determining the level of transaction costs.

- Kruskal-wallis test for capital value

We have seven samples representing seven different Capital value (in million euros) intervals.

- From 0 to 100
- From 101-200
- From 201-300
- From 301-500
- From 501-600
- From 601-700
- Over 700

$H = 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=18, number of observations

n_i represents the number of observations of one of the k samples

$n_1=4$

$n_2=3$

$n_3=2$

$n_4=2$

$n_5=2$

$n_6=2$

$n_7=3$

k is the number of samples we are comparing (seven samples)

R_i is the rank sum in sample i

$H < X^2 (k-1), (1-\alpha)$

Since H is smaller than the Chi-square critical with 6 degrees of freedom at a significance level of $\alpha = 0.05$, there is evidence ***to accept the null hypothesis***. Therefore, we may conclude that all samples have the same median. Capital Value IS NOT a significant variable for our model.

- Kruskal-wallis test for number of bidders

We have five samples depending on the number of bidders submitting proposals.

- 1 or 2 bidders
- 3 or 4 bidders
- 5 or 6 bidders
- 7 or 8 bidders
- Over 8 bidders

$H = 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=18, number of observations

n_i represents the number of observations of one of the k samples

n_1=2

n_2=7

n_3=3

n_4=1

n_5=5

k is the number of samples we are comparing (five samples)

R_i is the rank sum in sample i

H<*X^2 (k-1), (1-α)*

Since H is smaller than the Chi-square critical with 4 degrees of freedom at a significance level of α = 0.05, there is evidence ***to accept the null hypothesis***. Therefore, we may conclude that all samples have the same median. They come from identical populations, the number of bidders is not a signifcant variable in our model.

ii. Wilcoxon rank sum tests

The Wilcoxon rank sum test is a nonparametric alternative to the two-sample t-test, allowing us to compare two medians. The test is run conducting pairwise comparisons; in our case (where k= 2) we just need to conduct one pairwise comparison.

For the purpose of our analysis, the Wilcoxon rank sum test assesses the null hypothesis; H_0: Both samples have the same median, versus H_1: Both have different location.

In other words, accepting the null hypothesis implies that the two samples are drawn from a single population, and therefore that the distribution of the variable is the same in both samples.

When sample sizes are greater than 10, then we treat the distribution of the statistic as if it were normal. The test statistic, W, would be normally distributed with mean, E (W) and standard deviation $\sigma_{W.}$

The standardised test statistic would be as follows:

$z= W-E(W)/ \sigma_{W.}$

The Wilcoxon test rank all observations (8 plus 10) of the combined sample. Each observation has a rank, The W statistic is the sum of the ranks for obsevations from one of the sample (negotiated procedure), W= SUM OF THE RANKS FOR OBSERVATIONS FROM SAMPLE OF NEGOTIATED PROCEDURES

The results of the Wilcoxon test, which evaluated the difference between medians for sample one (negotiated procedure) and sample 2 (open procedure) indicate significant differential transaction costs for negotiated and open procedures (z = 2,4434, p < .025).

Thus, all observations are not drawn from the same distribution, H_0 is not true and then we have evidence to reject the null hypothesis. We may conclude that the two population medians are not equal.

The p-value corresponding to the W rank sum test statistic is much lower than 0.025, our typical alfa level, providing convincing evidence that samples do not have the same median.

For the purpose of our study, we may expect different behaviour in terms of the volume of transaction costs, depending upon the procurement procedure used at the bidding phase.

Finding evidence against the null hypothesis help us confirm that the two samples (negotiated/ open) have different distributions and thus, the alternative hypothesis is accepted: Transaction costs are different depending on the procurement procedure. Open procedures are prone to smaller transaction costs than in the negotiated procedure.

b. *Nonparametric results for the private sector*

i. *Kruskal-wallis tests*

- Kruskal-wallis test for type of infrastructure

We have two samples representing two different types of Infrastructure: Roads and Railways

$H= 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=35, number of observations

n_i represents the number of observations of one of the k samples

n1=30 (road projects)

n2=5 (railway projects)

k is the number of samples we are comparing (two samples)

R_i is the rank sum in sample i

H> ***X^2 (k-1), (1-α)***

Since H is greater than the Chi-square critical with 1 degree of freedom at a significance level of α = 0.05, there is evidence ***to reject the null hypothesis***. Therefore, we may conclude that samples have different medians or locations. That is to say, the type of infrastructure is a significant variable in determining the level of transaction costs.

- Kruskal-wallis test for procurement procedure

We have two samples depending on the bidding procedure: Negotiated Procedure and Open Procedure.

$H= 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=35, number of observations

n_i represents the number of observations of one of the k samples

n1=21 (negotiated procedure projects)

n2=14 (open procedure projects)

k is the number of samples we are comparing (two samples)

R_i is the rank sum in sample i

H> ***X^2 (k-1), (1-α)***

Since H is greater than the Chi-square critical with 1 degree of freedom at a significance level of α = 0.05, there is evidence ***to reject the null hypothesis***. Therefore, we may conclude that samples have different medians or locations. That is to say, the procurement procedure is a significant variable in determining the level of transaction costs.

➢ Kruskal-wallis test for capital value

We have nine samples representing nine different Capital value (in million euros) intervals.

- From 0 to 100
- From 101-200
- From 201-300
- From 301-400
- From 401-500
- From 501-600
- From 601-700
- From 701-800
- Over 800

$H= 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=35, number of observations

n_i represents the number of observations of one of the k samples

$n_1=3$

$n_2=6$

$n_3=5$

$n_4=3$

$n_5=2$

$n_6=3$

$n_7=4$

$n_8=4$

$n_9=5$

k is the number of samples we are comparing (nine samples)

R_i is the rank sum in sample i

H<X^2 (k-1), (1-α)

Since H is smaller than the Chi-square critical with 8 degrees of freedom at a significance level of α = 0.05, there is evidence ***to accept the null hypothesis***. Therefore, we may conclude that all samples have the same median.

- Kruskal-wallis test for number of bidders

We have five samples depending on the number of bidders submitting proposals.

- 1 or 2 bidders
- 3 or 4 bidders
- 5 or 6 bidders
- 7 or 8 bidders
- Over 8 bidders

$H= 12/ N(N+1) \sum R_i^2/n_i - 3(N+1)$

where

N represents the total number of observations (all sample sizes combined)

N=35, number of observations

n_i represents the number of observations of one of the k samples

$n_1=3$

$n_2=13$

$n_3=11$

$n_4=2$

$n_5=6$

k is the number of samples we are comparing (five samples)

R_i is the rank sum in sample i

H<X^2 (k-1), (1-α)

Since H is smaller than the Chi-square critical with 4 degrees of freedom at a significance level of $\alpha = 0.05$, there is evidence ***to accept the null hypothesis***. Therefore, we may conclude that all samples have the same median. They come from identical populations, the number of bidders is not a signifcant variable in our model.

ii. Wilcoxon rank sum tests

The Wilcoxon rank sum test is run conducting pairwise comparisons; in our case (for the procurement procedure variable, where k= 2) we just need to conduct one pairwise comparison.

The Wilcoxon test, which evaluated the difference between medians for sample one (negotiated procedure) and sample 2 (open procedure), indicate significant differential transaction costs for negotiated and open procedures ($z = 4{,}7477$, $p < .025$).

Thus, all observations are not drawn from the same distribution, H_0 is not true and then we have evidence to reject the null hypothesis. We may conclude that the two population medians are not equal. The p-value corresponding to W rank sum test statistic is much lower than 0.025, our typical alfa level, providing convincing evidence that samples do not have the same median.

Finding evidence against the null hypothesis help us confirm that the two samples (negotiated/ open) have different distributions and thus, the alternative hypothesis is accepted: Transaction costs are different depending on the procurement procedure. Again, open procedures are prone to smaller transaction costs than in the negotiated procedure.

3. Conclusions

Conducting noparametric statistics has disclosed the following results:

To the public sector, ONLY the PROCUREMENT PROCEDURE arises as a significant variable for explaining transaction costs. Thus, nonparametrics disregard the type of infrastructure as an explanatory variable, meaning that the type of infrastructure has no impact on the preparation costs of the project. However, parametric analysis considered the type of infrastructure as a significant variable for the public sector.

By contrast, to the private sector, BOTH THE TYPE OF INFRASTRUCTURE AND THE PROCUREMENT PROCEDURE are significant variables for transaction costs.

Nonparametric techniques are probably less efficient than parametric procedures, and face more difficulties when detecting a significant result. Indeed, Type II error (β) is the conditional probability of not rejecting Ho, given that the null hypothesis is false. This type of error is greater in nonparametric analysis. Therefore, we should take into account the fact that when using *nonparametrics it is easier to end accepting the null hypothesis when it is not true.*

Actually, one of the striking results of the nonparametrics is that the variable CAPITAL VALUE is not a significant variable for neither sector, which lead us to conclude that such variable is not representative to the transaction costs, which in principle makes little sense.

Nevertheless, we do agree that though less efficient than parametric procedures, they may provide appropriate results where parametric may not, when sample sizes are small.

4. Annex

Private sector sample results

(Tables A.1- A.4)

Public sector sample results

(Tables A.5-A.8)

Table A.1. Nonparametric Test results (Private sector sample with type of infrastructure)

KRUSKAL-WALLIS TEST		
Type of Infrastructure	**Rank Sum**	**Observations (N)**
Roads	590	30
Railways	40	5
H-stat	5,5556	
df	1	
p-value	0,018421659	
Chi-square Critical (α= 0,05)	3,84	

Table A.2. Nonparametric Test results (Private sector sample with procurement procedure)

KRUSKAL-WALLIS TEST		
Procurement Procedure	**Rank Sum**	**Observations (N)**
Negotiated	519	21
Open	111	14
H-stat	22,5408	
df	1	
p-value	2,05727E-06	
Chi-square Critical (α= 0,05)	3,84	

WILCOXON RANK SUM TEST		
Procurement Procedure	**Rank Sum**	**Observations (N)**
Negotiated	519	21
Open	111	14
Test statistic, W	519	
Mean, E (W)	378	
Standard Deviation	29,6985	
p-value	0,0000013	
z Stat	4,7477	

Table A.3. Nonparametric Test results (Private sector sample with Capital value)

KRUSKAL-WALLIS TEST		
Capital Value	**Rank Sum**	**Observations (N)**
From 0 to 100	12	3
From 101-200	124	6
From 201-300	67	5
From 301-400	63	3
From 401-500	37	2
From 501-600	35	3
From 601-700	81	4
From 701-800	100	4
Over 800	111	5
H-stat	11,3214	
df	8	
p-value	0,184144693	
Chi-square Critical (α= 0,05)	15,51	

Table A.4. Nonparametric test results (Private sector sample with number of bidders)

KRUSKAL-WALLIS TEST		
Number of Bidders	**Rank Sum**	**Observations (N)**
1 or 2	42	3
3 or 4	241	13
5 or 6	249	11
7 or 8	37	2
over 8	61	6
H-stat	6,2561	
df	4	
p-value	0,180821511	
Chi-square Critical (α= 0,05)	9,488	

Table A.5. Nonparametric test results (Public sector sample with Type of Infrastructure)

KRUSKAL-WALLIS TEST		
Type of Infrastructure	**Rank Sum**	**Observations (N)**
Roads	101	12
Railways	70	6
H-stat	1,4825	
df	1	
p-value	0,223383927	
Chi-square Critical (α=0,05)	3,84	

Table A.6. Nonparametric test results (Public sector sample with Procurement Procedure)

KRUSKAL-WALLIS TEST		
Procurement Procedure	**Rank Sum**	**Observations (N)**
Negotiated	103,5	8
Open	67,5	10
H-stat	5,9704	
df	1	
p-value	0,014547981	
Chi-square Critical (α=0,05)	3,84	

WILCOXON RANK SUM TEST		
Procurement Procedure	**Rank Sum**	**Observations (N)**
Negotiated	103,5	8
Open	67,5	10
Test statistic, W	103,5	
Mean, E (W)	76	
Standard Deviation	11,2546	
p-value	0,00734	
z Stat	2,4434	

Table A.7. Nonparametric test results (Public sector sample with Capital value)

KRUSKAL-WALLIS TEST		
Capital Value	**Rank Sum**	**Observations (N)**
From 0 to 100	18,5	4
From 101-200	25	3
From 201-300	17	2
From 301-500	26	2
From 501-600	18	2
From 601-700	16,5	2
Over 700	50	3
H-stat	9,9423	
df	6	
p-value	0,127103017	
Chi-square Critical (α=0,05)	12,59	

Table A.8. Nonparametric test results (Public sector sample with number of bidders)

KRUSKAL-WALLIS TEST		
Number of Bidders	**Rank Sum**	**Observations (N)**
1 or 2 bidders	26	2
3 or 4 bidders	88,5	7
5 or 6 bidders	20	3
7 or 8 bidders	10	1
over 8 bidders	26,5	5
H-stat	7,2343	
df	4	
p-value	0,124012567	
Chi-square Critical (α=0,05)	9,488	