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Mechanism design for the increase of team performance: An economic experiment using O-Ring and Foolproof theories

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ABSTRACT

This study constructs an economic experiment following O-ring and Foolproof theories to investigate the relationship between group formation and performance. This study will evaluate whether, or not Thais favor to work in a sequential working process (O-ring theory) or in a brainstorming process (Foolproof theory). Moreover, it will figure out the optimal combination in a group and whether a good team should contain more talented persons or just a moderate person can lead a group of weak persons. It will also compare the performance of the formation that has equally moderate persons in the same team. The results reveal that the Thais favour towards the brainstorming process rather than the sequential working process. The best formation of a team in the sequential working process is the combination of as many talented persons as possible. A group with equally moderate persons and a moderate person among weak persons show no difference of performance in this setting. For the brainstorming process the best formation goes to both a group with as many talented persons as possible, and a team with equally moderate persons. The worse formation is a team with one moderate person among weak persons. Therefore, Thais should work by brainstorming process and not let only a moderate person lead many weak persons. However, when the sequential working process is a given job, the top performance can be reached by having as many talented persons as possible in the team.

Keywords: experimental economics, O-ring theory, foolproof theory, mechanism design, group performance

JEL classification: O13, Q42, Q43

1. Introduction

In a society combined with many talented, moderate and weak people, many may peel that a team filled with talented ones would do a greater job than another team which is allied with moderate or weak people. This idea compiles with Kramer's O-ring Theory. This theory states that the key success factors to maximize the team performance is that the abilities or skills of the member should be equally high. However in real situation, especially in Thai society, this theory has not yet been proved. Thus, this research aims at proving the Kramer's O-ring theory via an economic experiment,

However, the wide range of abilities among members in a team that combines talented and less talented members may create an uncertain team's performance.

The Foolproof theory states that a good of team can be combined with talented and less talented members and they can perfectly complement one another. This paper also aims to investigate whether the O-ring theory and Foolproof theory suits better to Thais working in team. Moreover, it will find out what kind of formation is the best when the team must work by sequential working process (O-ring). This study will also evaluate the best formation in the working with brainstorming process (Foolproof).

2. Purpose of Study

1) To find the best combination of members that would yield the highest performance in sequential working process (O-ring theory).
2) To find the best combination of members that would yield the highest performance in the brainstorming process (Foolproof theory).
3) To find the best working process for a given combination of team members.

3. Review literature

Yu and Orazem(2011) , supports O-ring theory and hypothesizes that hog production can be characterized by complementarities between new technologies, worker skills and farms size. Such production processes are consistent with Kremer's O-ring production theory. A single mistake in a sequential working process can lead to catastrophic failure of the whole production. This study gives an example in hog production. Mistakes that introduce disease or pathogens into the production facility can cause a total loss of the herd.

Mueller (2008), analyzes how individuals match for the purpose of setting up a new firm. This study found that individuals do not match with individuals with the same level of ability. It means that a group with equally moderate persons will be the worse formation in any type of working process.

4. Experiment design

In doing an experiment according to O-ring theory and Foolproof theory, the experiment was designed for 120 samples, and divided into 2 games. The first Scenario is the experiment of O-ring theory and the second Scenario is the experiment of Foolproof theory. Each Scenario was divided into 3 cases. The first case is the formation of 4 talented persons and 1 moderate person. Each case consisted of 8 groups and each group has 5 members.

First Scenario: Under the concept of O-ring theory, each group was assigned to do exactly the same activity but members in each group were assigned different roles. The action of the first member affects the second member. The action of second member affects the third member and so on and so forth until the best member. The total score was collected from every member in the group in the end. The score will be compared to other groups to summarize the results in different cases. The second case is the formation of 5 equally moderate persons. The third case is the formation of 1 moderate person and 4 weak persons.

To identify the ability level of a person we make him or her solve 5 difficult mathematical problems. If a person can get 5 points, he or she is classified as talented. A person who gets 4 or 3 points will be classified as moderate. The best will be classified as weak.

Rules:

1. A participant joins a group according to his or her pre-test score. However, he or she does not know which type of formation of his or her group.

2. A group is assigned to do a sequential work. Then the score is collected after the last person in the group finish the job. The time limit is 5 minutes. The problem is to solve the Root Mean Squared Error without calculator.

3. A group is assigned to repeat the work but starting from a different person clockwise.

4. Repeat the work with another different person; rotate clockwise again and again until everyone has been in the start position. In total, the group will do the work 5 times.

5. Summarize the scores of this group from all 5 rounds.

Second Scenario: Under the concept of Foolproof theory, each group was assigned the exact same activity, the 5 members in the group have to work together in order to past the activity.

In the experiment, all the members in a group have to work together to come up with the answer of math equation within 5 minutes which in this experiment was divided into 3 cases.

Rule

1. A participant joins a group according to his or her pre-test score. However, he or she does not know which type of formation of his or her group.

2. A group is assigned to do a brainstorming to solve the Root Mean Squared Error within 5 minutes.

3. There is NO repeat for each group

4. Summarize the scores of this group from just 1 round.

5. Method of data analysis

This research uses Panel Data Analysis and Non-parametric Statistics as follows:

5.1 Panel Data Analysis

The data from this experiment can be constructed to be a panel data. For the first Scenario, each group does the experiment 5 times. Then we have 5 observations for each group. Since we have 8 groups in a team formation and 3 formations, total member of observations is 5.8.3 = 120 observations. For the second Scenario, each group does the experiment only once. Therefore, total member of observations is 1.8.3 = 24 observations.

5.2 Non-Parametric Statistics

The objective of the usage of Non-parametric statistics is to compare the mean between different formations within the same working process. It also compares the mean between the same formations of two different working process. Since the data are from unpaired samples, this study uses Wilcoxon-Mann-Whitney test. Number of observations in each test is 8 for each set of data.

6. Method

This research constructs 3 models They are O-Ring model, Foolproof model, and O-Ring and Foolproof Cross model**.**

6.1 O-Ring model

The model is specified as follows:

$$Score_{Oring} = \alpha+\beta_1 x_1+\beta_2 x_2+\beta_4 x_4+\beta_5 x_5+\beta_6 x_6+\beta_7 x_7\beta_8 x_8+\beta_9 x_9+\beta_{10} x_{10}+\beta_{11} x_{11}$$

where x_1 = Dummy variables for group 1.

x_2 = Dummy variable for group 3.

x_4 = Standard deviation of the pre-test scores.

x_5 = The mean value of the pre-test scores.

x_6 = Highest score of the pre-test.

x_7 = Lowest score of the pre-test.

x_8 = Dummy variable for starting with the best person of the group.

x_9 = Dummy variable for starting with the weakest person of the group.

x_{10} = Dummy variable for ending with the best person of the group.

x_{11} = Dummy variable for ends with the weakest person of the group.

Therefore:

x_1, x_5, x_6, x_8, x_{10} are expected to have positive relationship with the dependent variable (score).

x_2, x_4, x_7, x_9, x_{11} are expected to have negative relationship with the dependent variable (score).

6.2 Foolproof model

The model is specified as follows:

$$Score_{Foolproof} = \alpha+\beta_1 x_1+\beta_2 x_2+\beta_4 x_4+\beta_5 x_5+\beta_6 x_6+\beta_7 x_7$$

where x_1 = Dummy variables for group1.

x_2 = Dummy variable for group 3.

x_4 = Standard deviation of the pre-test scores.

x_5 = The mean value of the pre-test scores.

x_6 = Highest score of the pre-test.

x_7 = Lowest score of the pre-test.

Therefore:

x_1, x_5, x_6, are expected to have positive relationship with the dependent variable (score).

x_2, x_4, x_7 are expected to have negative relationship with the dependent variable (score).

6.3 O-Ring and Foolproof Cross model

$$Score_{Both} = \alpha+\beta_1 x_1+\beta_2 x_2+\beta_4 x_4+\beta_5 x_5+\beta_6 x_6+\beta_7 x_7+\beta_8 x_8$$

where x_1 = Dummy variables for group 1.

x_2 = Dummy variable for group 3.

x_4 = Standard deviation of the pre-test scores.

x_5 = The mean value of the pre-test scores.

x_6 = Highest score of the pre-test.

x_7 = Lowest score of the pre-test.

x_8 = 1 assume to be under the concept of O-Ring, and 0 assume to be under the concept of Foolproof.

Therefore:

x_1, x_5, x_6, are expected to have positive relationship with the dependent variable (score).

x_2, x_4, x_7 are expected to have negative relationship with the dependent variable (score).

x_8 is a testing variable, the relationship with dependent variable is still uncertain.

7. Result

The results are divided into 2 parts, Panel Data analysis and non-parametrical statistic analysis.

Part 1 Panel Data Analysis

Panel data analysis uses fixed effect model and random effect model to analyze the data and uses the Hausman test to select a better model between the fixed and random effects models (Suriya, 2010).

The results of the econometric models are shown as follows:

1.) Fixed Effect Model

TABLE1: Fixed effect Estimation of O-Ring Model

Dependent variable: Score						
Number of obs.		120				
Score	Coef.	Std.Err.	z	P>l z l	[95% Conf. Interval]	
x1	dropped					
x2	dropped					
x4	2.879897	2.86224	1.01	0.317	-2.79297	8.552763
x5	-2.482149	1.675456	-1.48	0.141	-5.802849	0.8385508
x6	-1.107824	1.13399	-0.98	0.331	-3.355354	1.139707
x7	2.212722	1.422225	1.56	0.123	-0.6060809	5.031526
x8	1.110922	0.9873842	1.13	0.623	-0.8460414	3.067886
x9	0.63292	0.7611113	0.83	0.407	-0.8755778	2.141418
x10	-0.0425142	0.9994491	-0.04	0.966	-2.02339	1.938361
x11	0.6190733	0.7151849	0.87	0.389	-0.7984	2.036546
_cons	11.16135	6.003828	1.86	0.066	-0.7380457	23.06074
sigma_u	2.6364376					
sigma_e	2.6426435					
rho	0.49882445					

Source: Calculation using Stata 10

TABLE2: Fixed effect Estimation of Foolproof Model

Dependent variable: Score						
Number of obs.		24				
Score	Coef.	Std.Err.	z	P>l z l	[95% Conf. Interval]	
x1	(dropped)					
x2	(dropped)					
x4	2.186094	7.459005	0.29	0.773	-13.55103	17.92322
x5	-2.940171	4.318852	-0.68	0.505	-12.05215	6.17181
x6	2.366543	3.018994	0.78	0.444	-4.002977	8.736064
x7	3.326925	3.594756	0.93	0.368	-4.257347	10.9112
_cons	87.89532	15.99118	5.5	0	54.15687	121.6338
sigma_u	1.0138348					
sigma_e	3.1673786					
rho	0.02933375					

Source: Calculation using Stata 10

TABLE3: Fixed effect Estimation of O-Ring & Foolproof Model

Dependent variable: Score						
Number of obs.		144				
Score	Coef.	Std.Err.	z	P>l z l	[95% Conf. Interval]	
x1	(dropped)					
x2	(dropped)					
x4	2.329227	2.639583	0.88	0.379	-2.89071	7.549163
x5	-2.32735	1.52835	-1.52	0.13	-5.349754	0.6950551
x6	-0.4547309	1.068358	-0.43	0.671	-2.567473	1.658012
x7	2.058127	1.272108	1.62	0.108	-0.4575436	4.573797
x8	-91.65583	0.6139247	-149.29	0	-92.86991	-90.44176
_cons	100.6079	5.682019	17.71	0	89.37134	111.8444
sigma_u	2.2131767					
sigma_e	2.7455546					
rho	0.39386171					

Source: Calculation using Stata 10

There is no significant variable in this model. This can due to two reasons. First, the number of observation is not enough, only 24 in the model. Second, it may be not really significant. However, the first reason is more feasible as just 24 observations is less than 30 which might not be enough for traditional statistics. To confirm this, we will see the result from Non-parametric Statistic to be the second evidence on this matter.

2.) Random Effect Model

TABLE 4: Random Effect Estimating of O-Ring Model

Dependent variable: Score						
Number of obs.		120				
Score	Coef.	Std.Err.	z	P>l z l	[95% Conf. Interval]	
x1	3.343835	1.866185	1.79	0.073	-0.3138205	7.00149
x2	-1.858874	2.164484	-0.86	0.39	-6.101184	2.383437
x4	2.879897	2.86224	1.01	0.314	-2.72999	8.489784
x5	-2.482149	1.675456	-1.48	0.138	-5.765983	0.8016849
x6	-1.107824	1.13399	-0.98	0.329	-3.330402	1.114755
x7	2.212722	1.422225	1.56	0.12	-0.574787	5.000232
x8	1.110922	0.9873842	1.13	0.261	-0.8243154	3.04616
x9	0.63292	0.7611113	0.83	0.406	-0.8588307	2.124671
x10	-0.0425142	0.9994491	-0.04	0.966	-2.001398	1.91637
x11	0.6190733	0.7151849	0.87	0.387	-0.7826634	2.02081
_cons	10.66636	6.072161	1.76	0.079	-1.234858	22.56758
sigma_u	0					
sigma_e	2.642644					
rho	0					

Source: Calculation using Stata 10

TABLE 5: Random Effect Estimating of Foolproof Model

Dependent variable: Score						
Number of obs.		24				
Score	Coef.	Std.Err.	z	P>l z l	[95% Conf. Interval]	
x1	-0.8261586	0.4971413	-0.17	0.868	-10.56995	8.917632
x2	-2.016725	5.769414	-0.35	0.727	-13.32457	9.291119
x4	2.186094	7.459005	0.29	0.769	-12.43329	16.80548
x5	-2.940171	4.318852	-0.68	0.496	-11.40496	5.524623
x6	2.366543	3.018994	0.78	0.433	-3.550576	8.283663
x7	3.326925	3.594756	0.93	0.355	-3.718667	10.37252
_cons	88.84295	16.19167	5.49	0	57.10785	120.5781
sigma_u	0					
sigma_e	3.1673786					
rho	0					

Source: Calculation using Stata 10

TABLE 6: Random Effect Estimating of O-ring & Foolproof Model

Dependent variable: Score						
Number of obs.		144				
Score	Coef.	Std.Err.	z	P>l z l	[95% Conf. Interval]	
x1	2.693459	1.759277	1.53	0.126	-0.7546613	6.14158
x2	-1.695213	2.041673	-0.83	0.406	-5.696818	2.306393
x4	2.329227	2.639583	0.88	0.378	-2.844262	7.502715
x5	-2.32735	1.52835	-1.52	0.128	-5.32286	0.6681611
x6	-0.4547309	1.068358	-0.43	0.67	-2.548674	1.639212
x7	2.058127	1.272108	1.62	0.106	-0.4351586	4.551412
x8	-91.65583	0.6139247	-149.29	0	-92.8591	-90.45256
_cons	100.2751	5.752684	17.43	0	89.00008	111.5502
sigma_u	0					
sigma_e	2.7455546					
rho	0					

Source: Calculation using Stata 10

Only one variable is significant in this model. It is x_1 which represents the formation of 4 talented persons with 1 moderate person. It reveals that this kind of formation tends to produce higher score than other formations.

Variable x_2 is not statistically significant. Therefore, it shows that there is no difference in team performance between the formation of one moderate person among weak persons and the formation of equally-moderate persons.

The only negatively significant variable in this model is x_8 which represents the sequential working process (Foolproof). It reveals that when the Thai work in the sequential process, they tend to produce less score than working by brainstorming process.

Part 2: Non-parametric statistical analysis

The results from the Non-parametric Statistics of the O-ring Model show that the mean score of the formation of 4 talented persons with 1 moderate person outperforms that of other formations. It also shows that the mean score of the formation of one moderate person among weak persons and the formation of equally-moderate persons create no difference in team performance.

TABLE 7: Comparison of the mean score of different formations within the O-ring Model.

Wilcoxon Mann Whistney test				
Group12	obs.	Rank sum	Expected	
1	8	88	68	
2	8	48	68	
combined	16	136	136	
Z	2.157	Prob> l Z l	0.031	
over score12	mean	std.Err.	[95% conf. Interval]	
1	6.625	0.4934391	5.57326	7.67674
2	5.17125	0.2560095	4.625579	5.716921
Group23	obs.	Rank sum	Expected	
2	8	62.5	68	
3	8	73.5	68	
combined	16	136	136	
Z	-0.605	Prob> l Z l	0.5449	
over score23	mean	std.Err.	[95% conf. Interval]	
2	5.17125	0.2560095	4.625579	5.716921
3	5.475	0.2901662	4.856525	6.093475
Group13	obs.	Rank sum	Expected	
1	8	83	68	
3	8	53	68	
combined	16	136	136	
Z	1.69	Prob> l Z l	0.0911	
over score13	mean	std.Err.	[95% conf. Interval]	
1	6.625	0.4934391	5.57326	7.67674
3	5.475	0.2901662	4.856525	6.093475

Source: Calculation using Stata 10

TABLE 8: Comparison of the mean score of different formations within the Foolproof Model.

Wilcoxon Mann Whistney test (Foolproof Model)				
Fool12	obs.	Rank sum	Expected	
1	8	72	68	
2	8	64	68	
Combined	16	136	136	
Z	0.421	Prob> l Z l	0.6735	
over score12	mean	std.Err.	[95% conf. Interval]	
1	98.9175	0.7751565	97.26529	100.5697
2	98.6975	0.7324342	97.13635	100.2586
Fool23	obs.	Rank sum	Expected	
2	8	91.5	68	
3	8	44.5	68	
combined	16	136	136	
z	2.472	Prob> l Z l	0.0134	
over score23	mean	std.Err.	[95% conf. Interval]	
2	98.6975	0.7324342	97.13635	100.2586
3	94.9275	1.606367	91.50361	98.35139
Fool13	obs.	Rank sum	Expected	
1	8	94	68	
3	8	42	68	
combined	16	136	136	
z	2.731	Prob> l Z l	0.0063	
over score13	mean	std.Err.	[95% conf. Interval]	
1	98.9175	0.7751565	97.26529	100.5697
3	94.9275	1.606367	91.50361	98.35139

Source: Calculation using Stata 10

The results from the Non-parametric Statistics of the O-ring Model show that the mean score of the formation of 4 talented persons with 1 moderate person outperforms that of often formations. It also shows that the mean score of the formation of one moderate person among weak persons and the formation of equally-moderate persons create no difference in team performance.

TABLE 9: Comparison of the mean score of the same formation across the different working processes.

Wilcoxon Mann Whistney test (O-Ring&Foolproof Model)				
Group11	obs.	Rank sum	Expected	
10	8	100	68	
11	8	36	68	
combined	16	136	136	
z	3.381	Prob> l Z l	0.0007	
over score11	mean	std.Err.	[95% conf. Interval]	
10	98.9175	0.7751565	97.26529	100.5697
11	66.25	4.934391	55.73259	76.76741
Group22	obs.	Rank sum	Expected	
20	8	100	68	
21	8	36	68	
combined	16	136	136	
z	3.376	Prob> l Z l	0.0007	
over score22	mean	std.Err.	[95% conf. Interval]	
20	98.6975	0.7324342	97.13635	100.2586
21	51.7125	2.560095	46.25579	57.16921
Group33	obs.	Rank sum	Expected	
30	8	100	68	
31	8	36	68	
combined	16	136	136	
z	3.411	Prob> l Z l	0.0006	
over score33	mean	std.Err.	[95% conf. Interval]	
30	94.9275	1.606367	91.50361	98.35139
31	54.75	2.901662	48.56525	60.93475

Source: Calculation using Stata 10

Comparing the same formation across O-ring and Foolproof models, shows that the result from non-parametric statistic presents that brainstorming process is better than sequential process for all formation.

8. Conclusions

It is clear from both econometric and non-parametric statistic results that Foolproof Model suits and utilizes the behavior of the Thais talents skills and more than O-ring model. Working by brainstorming yields higher performance for a team than sequential working process. Therefore, to raise the team performance of Thais, a manager should set the working process that allow the team members to work together, show ideas and use expertise of the other member rather than set an individual to work separately in a sequential process.

Moreover, if an O-ring model is given, a manager should select as many talented persons as possible in a team to ensure the highest performance. By the Foolproof model, many talented persons or many moderate person are not different in producing team performance. However, it is advisable not to set a moderate person alone in a massive group of weak person otherwise he or she cannot help raising the team performance and yet suffer from the low performance of the team.

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