Online appendix
Leadership by Conditional Commitments

Appendix A

The purpose of this appendix is to demonstrate that positively increasing costs of contributing does not necessarily destroy the coordination equilibria obtained with a linear cost function. We modify the profit function by introducing quadratic costs, keeping benefits linear:

$$\pi_i = z_k - \beta\left(c_i\right)^2 + \alpha_k \sum_{j=1}^{n} c_j \tag{A1}$$

The marginal cost of own contribution is now $2\beta c_i$. Again the followers' return function shifts up at the point at which it triggers the leader's conditional contribution, denoted c_i^*. For a coordination game to exist, the follower's private benefit of providing c_i^* must be larger than or equal to the cost:

$$\alpha_F(c_i^* + b) \geq \beta\left(c_i\right)^2 \tag{A2}$$

which simplifies to:

$$b \geq \frac{\beta}{\alpha_F}\left(c_i^*\right)^2 - c_i^* \tag{A3}$$

In addition, the leader must profit from inducing the followers to contribute c^*. When the leader contributes b and each follower contributes c^*, substituting into equation A1 provides the profit function of the leader:

$$\pi_L = z_L - \beta b^2 + \alpha_L(b + (n-1)c^*) \tag{A4}$$

Substituting A3 into A4, assuming that the leader will not contribute more than what it takes to satisfy A3, and simplifying, the leader's profit can be expressed as a function of c^*:

$$\pi_L = z_L - \frac{\beta^3}{\left(\alpha_F\right)^2}\left(c^*\right)^4 + \frac{2\beta^2}{\alpha_F}\left(c^*\right)^3 + \beta\left(\frac{\alpha_L}{\alpha_F} - 1\right)\left(c^*\right)^2 + \alpha_L\left(n-2\right)\left(c^*\right) \tag{A5}$$

The function in A5 may or may not attain positive values, depending on the size of β. To maximize the profit function when it is positive, we take the first derivative wrt c^* and set it equal to zero:[1]

[1] The second order condition is $\pi_L''(c^*) = 2\frac{\beta}{\alpha_F^2}\left(6c^*\beta\alpha_F - 6\left(c^*\right)^2\beta^2 - \alpha_F^2 + \alpha_L\alpha_F\right) \leq 0$. Given that $(\alpha_L, \alpha_F) = \{(.40, .40), (.64, .32)\}$ the second order condition holds if $6c^*\beta\alpha_F - 6\left(c^*\right)^2\beta^2 \leq 0$ for T4 and T6 (in which $\alpha_F = \alpha_L$), and if $6c^*\beta\alpha_F - 6\left(c^*\right)^2\beta^2 \leq -\alpha_F^2$ for T5 and T7 (in which $2\alpha_F = \alpha_L$). Thus the second order condition holds for T4 and T6 if $\beta \geq \frac{\alpha_F}{c^*}$, and for T5 and T7 if $6\beta c^*(\alpha_F - \beta c^*) \leq -\alpha_F^2$.

$$\pi'_L(c^*) = -\frac{4\beta^3}{(\alpha_F)^2}(c^*)^3 + \frac{6\beta^2}{\alpha_F}(c^*)^2 + 2\beta\left(\frac{\alpha_L}{\alpha_F} - 1\right)(c^*) + \alpha_L(n-2) = 0 \qquad \text{(A6)}$$

The algebraic solutions to the polynomial in A6 are messy. As a numeric illustration we derive solutions given a parameter value of $\beta = .01$, while the other parameter values vary with treatments as in the experiment. In all these cases, the social optimum is that each follower contributes 80 ECU. Table A1 shows results for treatments T4-T7, in which the leader's promise is binding. The second column shows the two Pareto-ranked equilibria, while the last column shows aggregate contributions in the Pareto superior equilibrium, as a percentage of the socially optimal contribution level.[2]

Treatment	Equilibria $(c_L, \bar{c}_F)$	Percent of social optimum
T4	$(0,0)$ and $(45,67)$	75.0
T5	$(0,0)$ and $(64,64)$	80.0
T6	$(0,0)$ and $(45,67)$	75.0
T7	$(0,0)$ and $(64,64)$	80.0

Table A1: *Equilibrium leader contribution and equilibrium average follower contribution in treatments with binding promise when costs are quadratic and* $\beta = .01$

Appendix B

In this appendix we report non-parametric tests of differences in average follower behavior between treatments with explicit conditionality (T3–T10). We focus average follower contributions conditioned on: (1) whether the leader's promise is binding (automatic implementation) or not binding (implementation left to the leader's discretion); (2) whether endowments are uneven ($z_L = 200$) or even ($z_L = 100$); and (3) whether the benefits from the public account are shared evenly ($\alpha_L = 0.4$) or unevenly ($\alpha_L = 0.64$).

Binding promise:				
Yes	No	Endowment	Returns	p-value
T6 (8)	T9 (10)	Uneven	Even	.110
T4 (12)	T3 (10)	Even	Even	.056
T5 (8)	T8 (8)	Uneven	Uneven	.916
T7 (12)	T10 (10)	Even	Uneven	.391

Table B1: *WRS tests of differences in the average follower contribution by credibility of promise (number of groups)*

Endowment:				
Uneven	Even	Binding:	Returns	p-value
T6 (8)	T4 (12)	Y	Even	.002
T9 (10)	T3 (10)	N	Even	.019
T7 (12)	T5 (8)	Y	Uneven	.143
T10 (10)	T8 (8)	N	Uneven	.790

[2] The second order condition is satisfied in all of these cases.

Table B2: *WRS tests of differences in average follower contribution by endowment (number of groups)*

Returns:				
Even	Uneven	Endowment:	Binding	p-value
T6 (8)	T7 (12)	Uneven	Y	.031
T4 (12)	T5 (8)	Even	Y	.440
T9 (10)	T10 (10)	Uneven	N	.821
T3 (10)	T8 (8)	Even	N	.002

Table B3: *WRS tests of differences in average follower contribution by returns (number of groups)*

First, by comparing treatments vertically in Figure 1 in the main text (T4 vs. T3; T5 vs. T8; T6 vs. T9; T7 vs. T10), we appreciate that the effect of binding promises is positive except when benefits are unevenly distributed. Thus, being able to set forth binding promises seems to help leaders induce followers to contribute, but only if the proceeds from the public account are distributed evenly. Wilcoxon rank-sum (WRS) tests confirm this finding.[3] The results in Table B1 show that one effect (T4 vs. T3) is close to significance at the 5% level, while another (T6 vs. T9) is close to significance at the 10% level. Thus, binding promises seems to have an effect on average follower contributions only when benefits are evenly distributed.

Second, by comparing treatments that vary only concerning leader endowment in Figure 1 in the main text (T3 vs. T9; T8 vs. T10; T4 vs. T6; and T5 vs. T7), we find that the size of the leader's endowment has a positive effect on the average follower contribution in all four cases. Table B2, however, reveals that the effect is marginal at best when benefits are unevenly distributed. WRS tests confirm that big endowments help leaders induce followers to contribute only if proceeds are shared evenly.

Finally, by comparing treatments that vary only concerning how benefits are distributed in Figure 1 in the main text (T4 vs. T5; T6 vs. T7; T3 vs. T8; T9 vs. T10), we find that increasing the leader's MPCR (while simultaneously decreasing the MPCR of followers) appears to have a positive effect on the average follower contribution in two of the four cases (4 vs. 5; 3 vs. 8), but a negative effect in the other two cases (7 vs. 6; 9 vs. 10). Table B3. reveals that one effect in each direction is significant at the 5% level. Thus, based on Figure 1 and the WSR tests the isolated effect of unevenly distributed benefits seems indeterminate.

Appendix C

Are contributions declining over time? Does the effect of binding promises and large leader endowment occur from the start or develop through repeated interactions? Table C1 presents the results of a regression that includes the number of periods already played as a predictor, along with interactions between this variable and the two treatment dummies found to have effects in the main analysis. The results show with high level of confidence that, over all treatments, contributions decline over time, although only with around 1 ECU per period. Declining contributions is considered a "core fact" of public goods experiments. Our results show no significant interaction between temporal decline and binding promises or large leader endowments. Hence, it appears that these treatment variables' shift the entire contribution curve up while not affecting its slope, which remains negative throughout.

[3] We conducted pairwise Wilcoxon rank-sum tests of differences over treatments, using group averages over the 16 periods of play as observations. These tests take account of group differences caused by variations in strategic interaction and learning over time.

	Coefficient	*SdE*	*p*-value
Period	-1.04	.16	.000
Binding promise	7.91	3.80	.037
Large endowment	20.41	3.96	.000
Binding promise×Period	.09	.33	.792
Large endowment×Period	-.27	.35	.432
Constant	33.49	2.49	.000
R^2	0.12		
#Subjects	408		
#Observations	4 896		

Table C1: *Random (individual) effects GLS with robust standard errors clustered at the group level. Dependent variable: contributions.*

Are conditional and unconditional contributions substitutes? An interesting question is whether conditional and unconditional contributions are substitutes in generating follower contributions. Table C2 contains a regression that includes these two variables on the right-hand side, together with the two treatment dummies found to be effective in the previous analysis (large endowment, binding promise) and interaction terms between each of the former two variables and each of the latter two variables (i.e., four interaction terms). The results show that both conditional and unconditional contributions by the leader significantly increase follower contributions. Thus, the two types of leader contributions seem to be substitutes.

Does the effectiveness of conditional and unconditional contributions vary across treatments? The only interaction effect found to be significant is the one between unconditional contributions and binding promises. This interaction effect is negative. The lack of other significant interaction coefficients may be due to the presence of multicollinearity.

	Coefficient	*SdE*	*p*-value
Binding promise (BP)	11.031	4.491	.014
Large endowment (LE)	9.970	4.202	.021
Unconditional contribution (UC)	.341	.047	.000
Conditional contribution (CC)	.209	.039	.000
BP×UC	-.136	.055	.014
LE×UC	-.082	.055	.134
BP×CC	.019	.046	.682
LE×CC	-.032	.043	.451
Constant	5.874	2.811	.037
R^2	0.18		
#Subjects	312		
#Observations	3 744		

Table C2: *Random (individual) effects GLS with robust standard errors clustered at the group level. Dependent variable: follower contributions.*

Trade-off in target setting In our experiment, the optimal target is a function of the conditional commitment promised, and the optimal relationship between the two variables varies between treatments, as shown in section 3 of the main text. Table 2 in the main text lists

the theoretical equilibrium values for the two variables across the four treatments with binding promises. The mean values observed in the same groups are reported in Table C3. Comparing the two tables reveals that all the observed differences between treatments have the theoretically predicted sign. WRS tests indicate that most of the differences are significant (at the 1% level). For conditional promises, theory predicts five pair wise differences. All except one of these differences are significant (the exception being T6-T7). No difference is predicted between T4 and T5, and indeed the data shows no significant difference. For the targets, three of the six predicted differences are significant (T6-T4, T6-T5, and T7-T5). In sum, the variations across treatments are consistent with theory. However, the results also show that leaders set the targets too high relative to the conditional promises.

Treatment	Mean conditional promise	Mean target
T4	57.7	55.7
T5	61.0	50.9
T6	87.1	70.5
T7	95.1	61.7

Table C3: *Mean conditional promises and mean targets in treatments with binding promises*

We find no evidence of a hump-shaped relationship between Target and followers' contribution. Table C4 regresses follower contributions on the two treatment dummies found effective in the previous analysis (binding promise and large endowment), the leader's unconditional contribution, the leader's conditional contribution, the target set by the leader (the endogenous treshold), and the target squared. We appreciate that followers' contribution is a monotonically increasing function of Target in the interval we observe (Target squared turns out to be insignificant).

	Coefficient	*SdE*	*p*-value
Binding promise	7.589	3.215	.018
Large endowment	5.929	3.296	.072
Unconditional contribution	.172	.029	.000
Conditional contribution	.136	.024	.000
Target	.316	.122	.009
Target^2	-.001	.001	.354
Constant	1.134	2.786	.684
R^2	.20		
#Subjects	312		
#Observations	3 744		

Table C4: *Random (individual) effects GLS with robust standard errors clustered at the group level. Dependent variable: follower contributions.*

Similarly scatterplots treatment by treatment do not reveal any hump shaped relationship between target and average follower contributions (Figure C1). The lack of a single optimal target may relate to the fact that in our experiment tresholds (i.e. targets) are endogenous.

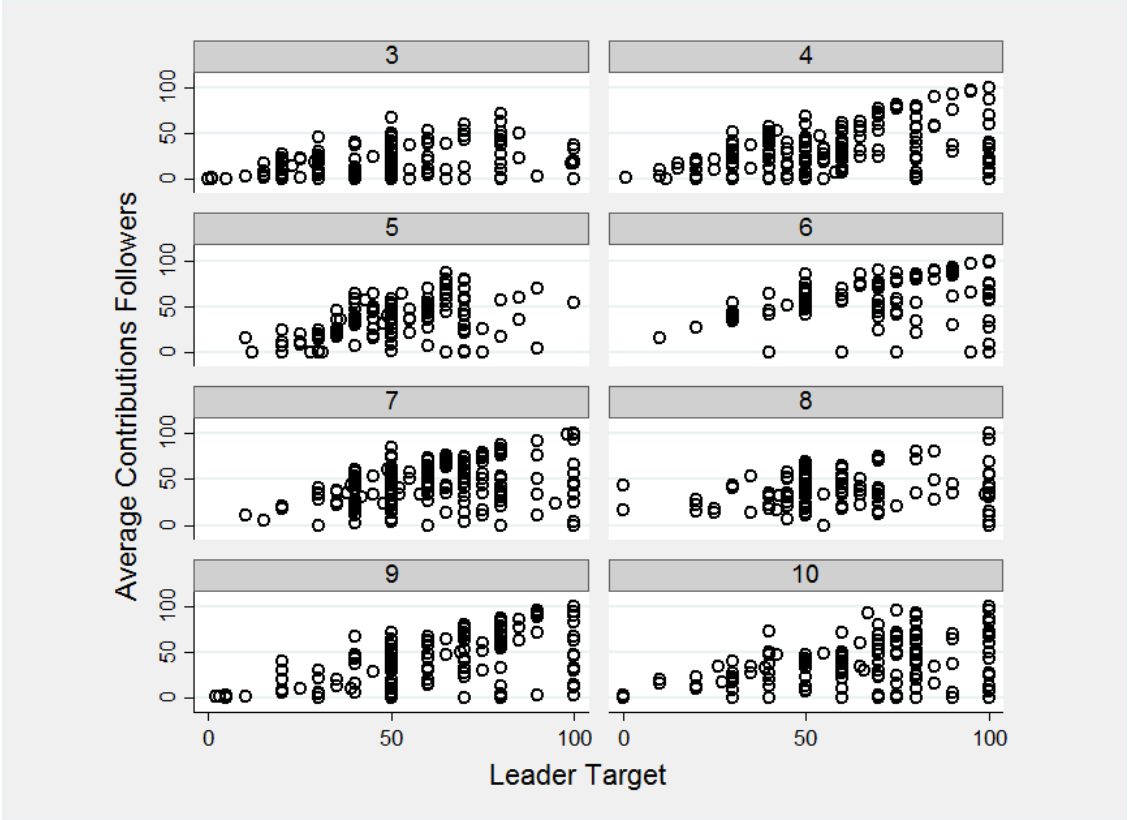


Figure C1: *Scatterplot of Average Follower Contributions by Leader Target, treatment by treatment..*

Appendix D

Sample instruction; T4, US session

Experimental Instructions

You are going to participate in an experiment financed by [institution x].

You will earn money. How much you earn depends on the decisions you make, as well as on the decisions made by other subjects.

All interactions are anonymous and are performed through a network of computers. The administrators of the experiment will not be able to observe your decisions during the experiment.

40 subjects participate in the experiment. All participants are in this room, have been recruited in the same way as you have, and are now reading the same instructions as you are for the first time. It is important that you do not talk to other participants until the experiment is over.

In the experiment you will earn Experimental Currency Units (ECUs). At the end of the experiment, you will be paid in cash based on your total earnings in ECUs from the experiment. The exchange rate from ECUs to US Dollars (US$) is:

1 ECU = 0.015 US$

The more ECUs you earn, the more cash (in US$) you will receive.

Detailed information about the experiment

The experiment consists of 16 separate periods. Groups of 4 participants are formed randomly from the participants present in the lab. You will never know which other participants are in your group. The group composition is secret for every participant.

Once a group has been formed, it remains unchanged for all the 16 periods of the experiment. These 16 periods are divided into 4 sets; thus, each set consists of 4 periods.

In each set, one group member is THE EARLY CONTRIBUTOR, while the other 3 group members are LATE CONTRIBUTORS. Each group member is the early contributor in one of the 4 sets. Which group member is the early contributor in which set is decided by random.

Example:

- Member 4 is the early contributor in set 1 (i.e., in periods 1, 2, 3, and 4);
- Member 1 is the early contributor in set 2 (i.e., in periods 5, 6, 7, and 8);
- Member 3 is the early contributor in set 3 (i.e., in periods 9, 10, 11, and 12);
- Member 2 is the early contributor in set 4 (i.e., in periods 13, 14, 15, and 16).

The group member being the early contributor will see this in an “Information Window", which will appear on his/her screen at the beginning of the set.

What you have to do

At the beginning of each period, each participant will receive an endowment of 100 ECUs.

Your task (as well as the task of your fellow group members) is to decide how much of your endowment you will contribute to a PROJECT. Whatever you do not contribute, you keep for yourself.

Each ECU you keep for yourself raises YOUR period earnings by one ECU. Thus, each ECU you keep for yourself yields money for YOU ALONE.

Each ECU that a group member contributes to the project is multiplied by 1.6 and divided equally on all four group members. Thus, each ECU you contribute to the project raises YOUR period earnings as well as the period earnings of each of YOUR FELLOW GROUP MEMBERS by 0.4 ECUs. The same holds for each ECU contributed by one of your fellow group members: Each ECU that any other member of your group contributes to the project increases the period earnings of each and every member of your group (including you) by 0.4 ECUs.

How you interact with your fellow group members in each period

Each period consists of the following three stages:

`Stage 1`: The early contributor makes an unconditional contribution of X ECUs ($X \geq 0$) to the project and promises to make an additional conditional and contribution of Y ECUs ($Y \geq 0$) in stage 3 provided the average contribution made by the late contributors in stage 2 equals at least Z ECUs. Any promise to make an additional contribution is binding and will be automatically implemented by the computer, provided that the average contribution made by the late contributors in stage 2 equals at least Z ECUs.

`Stage 2`: Having observed the early contributor's unconditional contribution and promise (but not the contributions made by other late contributors), each late contributor makes an (unconditional) contribution to the project.

`Stage 3`: The promise made by the early contributor in stage 1 is automatically implemented by the computer. Thus, provided that the average contribution made by the late contributors in stage 2 equals at least Y ECUs, the computer adds the promised Z ECUs to the early contributor's contribution.

Earnings

Your income in each round is the sum of the ECUs you keep to yourself and your income from the project:

ECUs you keep:	100− contributions to the project
+ Income from the project:	0.4× sum of all contributions to the project
= Period earnings:	

Examples

`Example 1`: Member 1 is the early contributor in period 1 and contributes 30 ECUs in stage 1. Moreover, member 1 promises to make an additional contribution of 30 ECUs in stage 3, provided the three other members' average contribution in stage 2 equals at least 50 ECUs. Knowing the contribution and the conditional promise of the early contributor, the three other members of the group contribute 0 ECUs , 100 ECUs and 80 ECUs, respectively, in stage 2. In other words, the average stage 2 contribution is 60 ECUs (and thus satisfies the early contributor's minimum requirement of 50 ECUs). In stage 3, therefore, the computer adds 30 ECUs to the early contributor's contribution. Member 1's earnings in period 1 will then be as follows:

ECU he or she keeps:	$100 - 30 - 30$	$= 40$
+ Income from the project:	$0.4 \times (30 + 0 + 100 + 80 + 30) = 0.4 \times 240$	$= 96$
= Period earnings:	$40 + 96$	$= 136$

In contrast, the period earnings of the group member contributing 0 ECUs to the project will be as follows:

ECU he or she keeps:	$100 - 0$	$= 100$
+ Income from the project:	$0.4 \times (30 + 0 + 100 + 80 + 30) = 0.4 \times 240$	$= 96$
= Period earnings:	$100 + 96$	$= 196$

`Example 2`: Member 1 is the early contributor in period 1 and contributes 20 ECUs in stage 1. Moreover, member 1 promises to make an additional contribution of 60 ECUs in stage 3, provided the three other members' average contribution in stage 2 equals (at least) 80 ECUs. Knowing the contribution and the conditional promise of the early contributor, the three other members of the group contribute 60 ECUs, 80 ECUs, and 100 ECUs, respectively, in stage 2. In other words, the average stage 2 contribution is 80 ECUs (and thus satisfies the early contributor's minimum requirement of 80 ECUs). In stage 3, therefore, the computer adds 60 ECUs to the early contributor's contribution. Member 1's earnings in period 1 will then be as follows:

ECU he or she keeps:	$100 - 20 - 60$	$= 20$
+ Income from the project:	$0.4 \times (20 + 60 + 80 + 100 + 60) = 0.4 \times 320$	$= 128$
= Period earnings:	$20 + 128$	$= 148$

In this example, all members' contributions are equal (here: 80 ECUs). As a result, their period earnings will also be equal (here: 148 ECUs).

`Example 3`: Member 1 is the early contributor in period 1 and contributes 0 ECUs in stage 1. Moreover, member 1 promises to contribute 100 ECUs in stage 3, provided the other members' average contribution in stage 2 equals at least 80 ECUs. Knowing the contribution and the conditional promise of the early contributor, the three other members of the group contribute 0 ECUs each in stage 2. The average stage 2 contribution is thus 0 ECUs, which does not satisfy the early contributor's minimum requirement of 80 ECUs. In period 3, therefore, the computer adds nothing to the early contributor's contribution. This means that all members contribute 0 ECUs. Every member's period earnings will then equal his or her endowment (100 ECUs).

The information you receive at the end of each period

At the end of each period, you will receive information about the number of ECUs contributed by each of your fellow group members as well as about your own period earnings.

Your final earnings

Your final earnings will be calculated as follows:

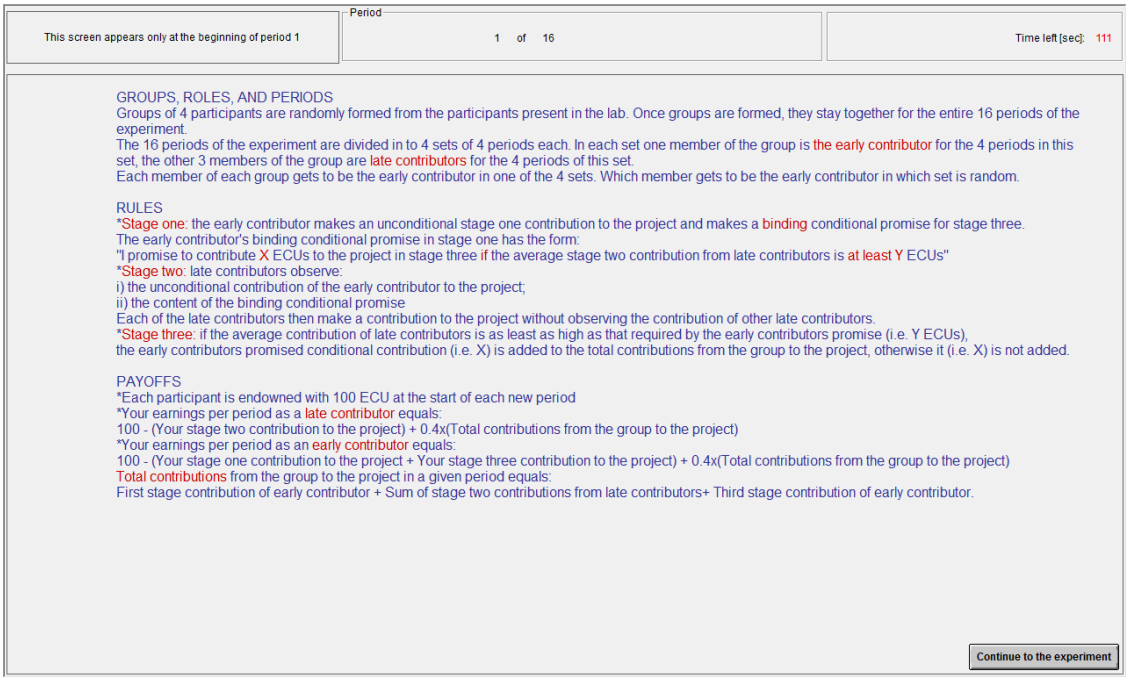
1. Your earnings in the 16 periods will be added up.

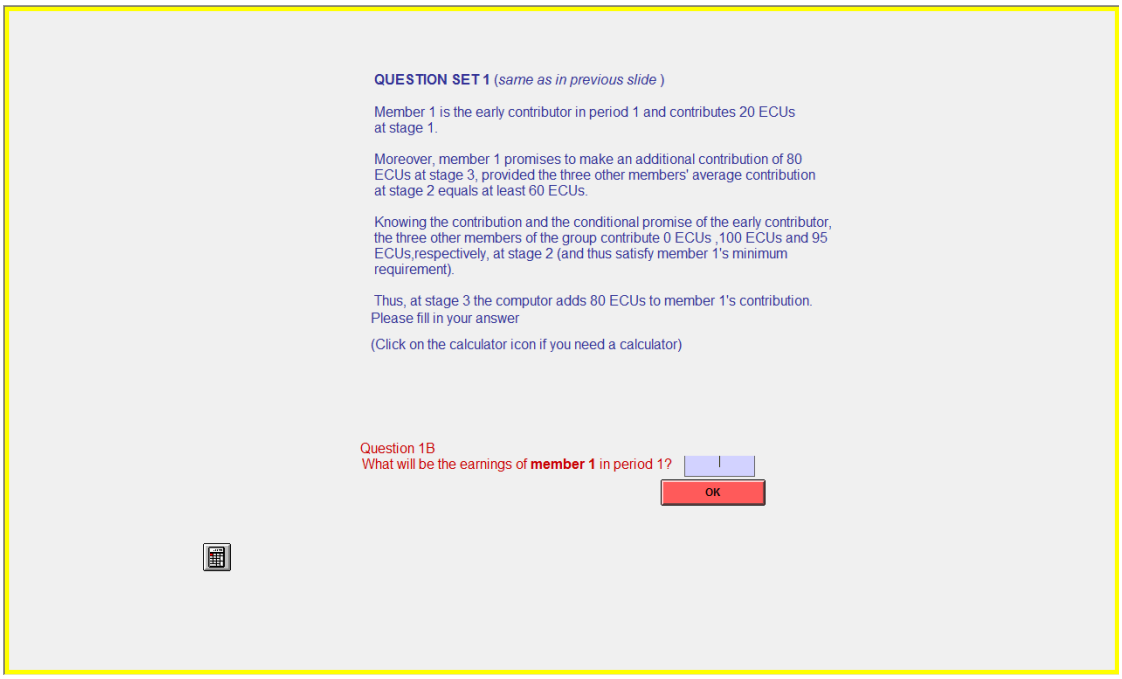
2. The resulting sum will be converted to US$ and paid to you in cash.

Before the experiment starts, we will run a control questionnaire to verify your understanding of the experiment.

Please remain seated quietly until the experiment starts. If you have any questions, please raise your hand now.

Sample screen shots T4:
contains first and last of a total of 8 control questions; information screen prior to first game; leader and follower decision screens; two common feedback screens.





QUESTION SET 2 (*same as in previous slide*)

Member 1 is the early contributor in period 1 and contributes 0 ECUs at stage 1.

Moreover, member 1 promises to contribute 100 ECUs at stage 3, provided the other members' average contribution at stage 2 equals at least 80 ECUs.

Knowing the contribution and the conditional promise of the early contributor, the three other members of the group contribute 80 ECUs each at stage 2 (and thus satisfy member 1's minimum requirement).

Thus at stage 3, the computor adds 100 ECUs.

Please fill in your answer

(Click on the calculator icon if you need a calculator)

Question 2D
What will be the earnings of **member 4** in period 1?

OK

This is stage one

Period 1 of 16

Time left [sec]: 42

You are the early contributor

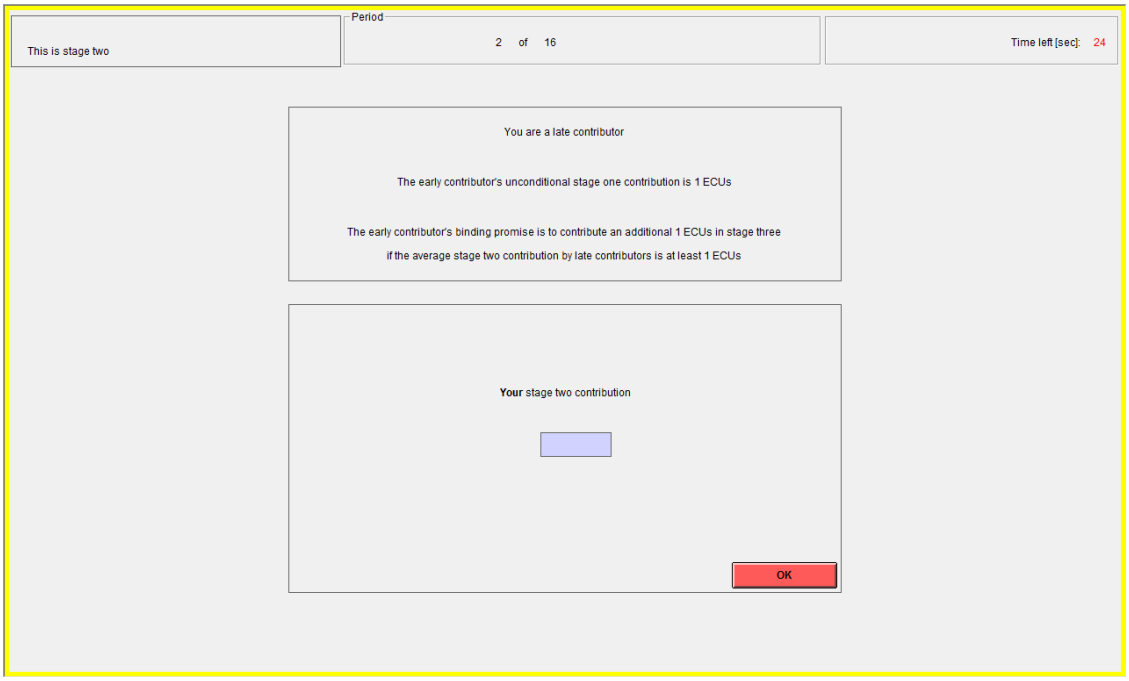
Your **unconditional** stage one contribution

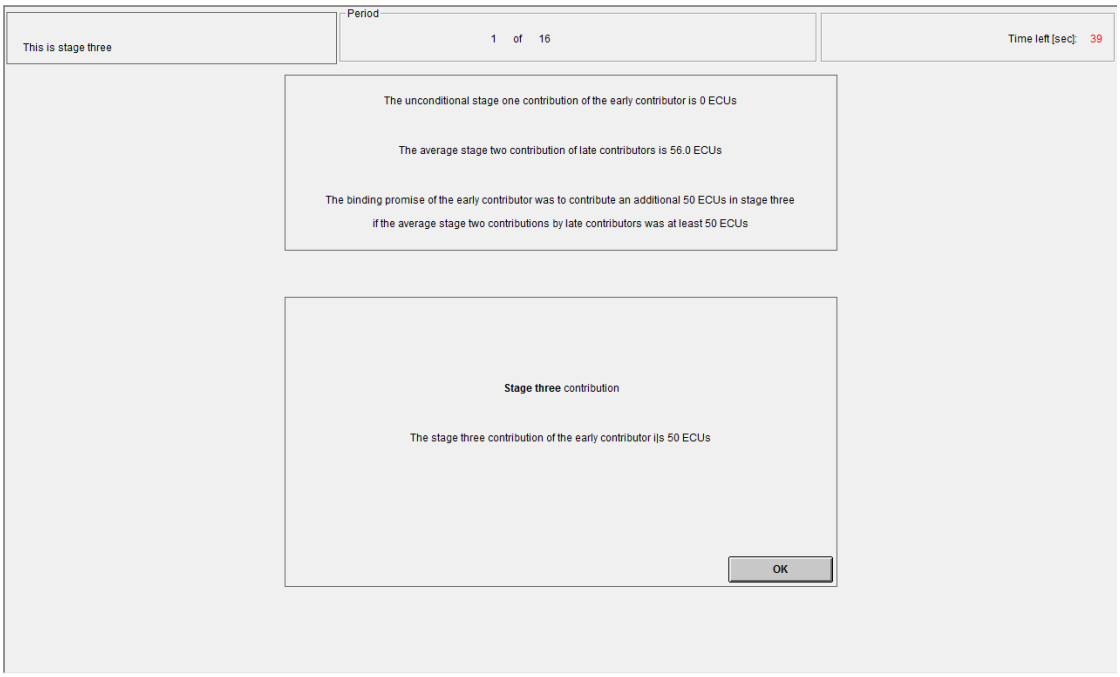
Your **binding conditional** promise

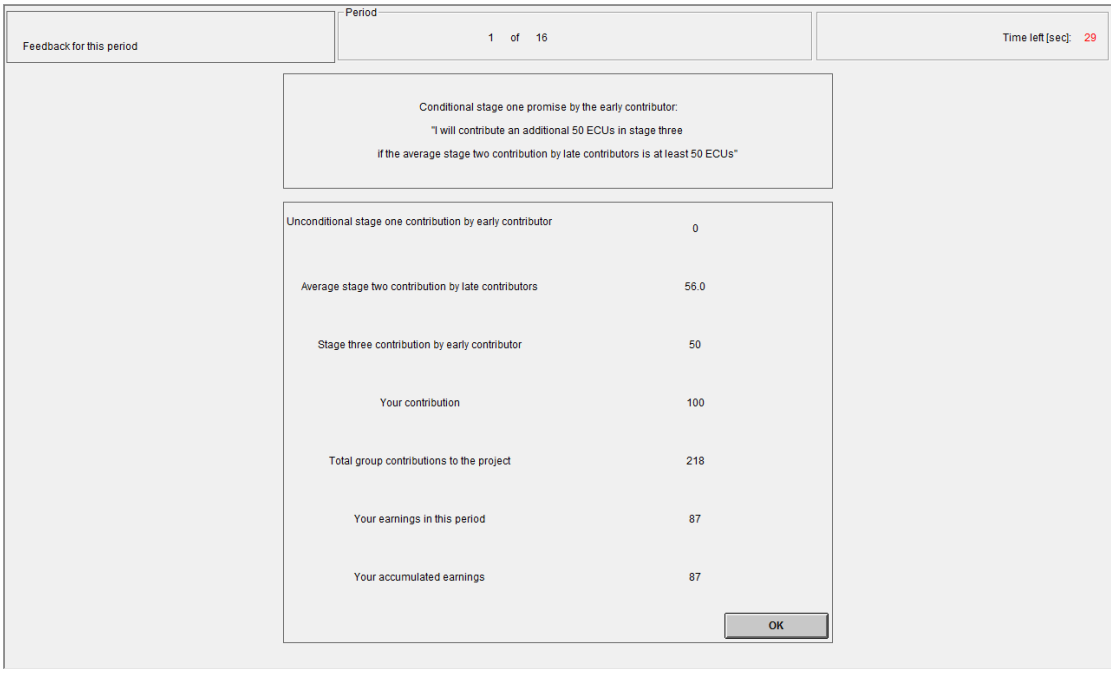
If the **average** stage two contribution by late contributors is **at least**

my stage three contribution will be

OK


This is stage two
Period
2 of 16
Time left [sec]: 24
You are a late contributor
The early contributor's unconditional stage one contribution is 1 ECUs
The early contributor's binding promise is to contribute an additional 1 ECUs in stage three
if the average stage two contribution by late contributors is at least 1 ECUs
Your stage two contribution
OK


This is stage three
Period
1 of 16
Time left [sec]: 39
The unconditional stage one contribution of the early contributor is 0 ECUs
The average stage two contribution of late contributors is 56.0 ECUs
The binding promise of the early contributor was to contribute an additional 50 ECUs in stage three
if the average stage two contributions by late contributors was at least 50 ECUs
Stage three contribution
The stage three contribution of the early contributor is 50 ECUs
OK


Feedback for this period
Period
1 of 16
Time left [sec]: 29
Conditional stage one promise by the early contributor:
"I will contribute an additional 50 ECUs in stage three
if the average stage two contribution by late contributors is at least 50 ECUs"
Unconditional stage one contribution by early contributor 0
Average stage two contribution by late contributors 56.0
Stage three contribution by early contributor 50
Your contribution 100
Total group contributions to the project 218
Your earnings in this period 87
Your accumulated earnings 87
OK