A simple economic teaching experiment on the hold-up problem

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by

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Abstract: The hold-up problem is central to the theory of incomplete contracts. It shows how the difficulty to write complete contracts and the resulting need to renegotiate can lead to underinvestment. We describe the design of a simple teaching experiment that illustrates the hold-up problem. The model used is a simple perfect information game. The experiment can hence also be used to illustrate the concept of subgame perfect equilibrium and the problem of making non-binding commitments.

Introduction

Teaching experiments can be a very powerful tool to illustrate economic key concepts. Rather than being exposed to an economic concept only theoretically, the students experience first hand the underlying economic problem in the classroom and thereby develop an intuitive understanding of the concept before it is formally discussed. This can help students both to understand the theoretical arguments better and to value their practical relevance more.

The hold-up problem (see Hart, 1995) results from situations where it is difficult to write complete contracts. A historic example of how the difficulty to judge quality, and hence the difficulty to write contacts contingent on quality, can lead to a hold-up problem is provided in a recent paper by Harrison and Markevich (2007). They write "When A has had to make a prior commitment to a relationship with B, B can `hold up' A for the value of that commitment. This roughly describes the power of Industry over the Army in the Soviet defense market. The normal use that Industry made of this power was to default on quality. The Army's counter-action took the form of deploying agents through industry with the authority to verify quality and reject substandard goods. The struggle ended not in victory for one side but in a compromise." The hold-up problem leads to severe economic cost, in this case the provision of too low quality and the need for spying ('monitoring').

Another often quoted historic example (sharply disputed by Coase, 2000) concerned the US car industry in the 1920's. It is claimed that Fisher Body held up General Motors, with whom they had an exclusive contract to supply body parts. They were paid at 17% above non-capital costs and held up GM by locating their body plants far away from GM's assembly plants and by producing inefficiently. The possibility of a hold up arose because the sharp increase in the demand for cars had not been foreseen

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[1] We wish to thank HEFCE for financial support, John Sloman and the rest of the Economics Network for feedback on our experimental design. We also wish to thank David Kelsey for providing an initial set of students and Marc Hodes for describing the software used for aerodynamic design in the auto industry.

when the contract was written. It has been argued that this hold up led to the acquisition of Fisher Body by GM. Hart (1995) uses the hold-up problem to explain the formation of firms and their financial structure.

Our teaching experiment is a simplified version of the hold-up problem which we developed for a lecture on corporate finance. One party called the “Buyer” (GM or the Army in the above examples) has the possibility of making a relation-specific investment whose value depends on the delivery of an input by another party called the “Supplier” (Fisher Body or the Industry in the examples). If the investment is made, this gives the supplier the possibility to hold up the Buyer by raising the price. (In the examples the inputs were not produced in the required quality or quantity on time). In case the price is raised, the Buyer can, at a loss to herself, change the supplier.

We run two treatments which differ only by one parameter. In both treatments it is optimal for the Supplier to hold up the buyer and for the Buyer to accept the hold up. In the first treatment it is optimal to invest even if there is a hold-up while in the second treatment it is better not to invest due to the hold up. We choose this set-up because it allows students first to learn that there will be a hold-up and then to experience the economic consequence of underinvestment caused by the hold-up problem.

In our experiment students typically learn to play according to subgame perfect equilibrium (Selten 1965). The experiment is therefore also useful to introduce this concept in a game theory class, perhaps coupled with other experiments (e.g. on the ultimatum game or trust game to illustrate the limitations of this concept.)

We will discuss both a computerized internet version and a non-computerized version of the experiment. Both can be run conveniently in less than an hour and there will typically be time left for discussions. The computerized version can be run over the Internet using our Finance and Economics Experimental Laboratory at Exeter (FEELE) website. In the next section we describe the game illustrating the hold-up problem and its analysis in more detail. In Section 3 we describe the computerized version and the hand-run version of the experiment. Section 4 discusses some results obtained from running the experiments. The Appendix provides the graphs of the extensive forms that we use and which should be given to participating students and also some further material needed for the hand-run version

Description and Analysis of the Hold-Up Experiment

The Hold-Up Problem

Two firms, referred to as the buyer and the supplier, are engaged in a long term business relationship. The buyer has an opportunity to invest in some specialist equipment that will increase her profits in the long term but only if the relationship continues with the same supplier.

If the two firms could agree a binding contract at the time the investment is made, covering the entire period of the investment, anticipating all possible outcomes and providing protection for them both in every situation that might arise, then the buyer could make the investment with confidence and both firms could enjoy higher profits. Unfortunately, it is not possible to draw up such a contract because of (a) unforeseeable external factors, such as global technology shifts or changes in consumer lifestyles, (b) lack of trust, for instance the difficulty the buyer has in re-assuring the supplier that the money has been invested properly or indeed that it has been invested at all, (c) asymmetric information, for instance the supplier may over-estimate the cost of the investment to the buyer, and (d) quality problems, in that the supplier has an incentive to supply goods of inferior quality to those in the contract and it is prohibitively costly for the buyer to enforce quality compliance, despite inferior quality being readily apparent.

In consequence, the initial contract can only cover the short term and sooner or later it has to be re-negotiated, which provides an opportunity for the supplier to 'hold up' the buyer. The supplier knows that the investment represents a significant sunk cost for the buyer and attempts to use this as leverage to negotiate an increase in her prices; it is difficult for the buyer to know whether or not the increase is reasonable. It harms both parties if the renegotiations are unsuccessful: the buyer has made a wasted investment and the supplier has lost a major customer.

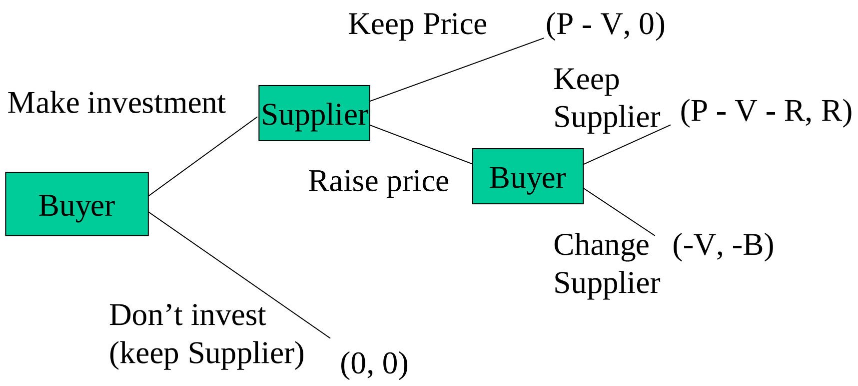
The hold-up problem leads to inefficiency when the buyer is reluctant to make the investment ex ante because of a fear that the supplier will exploit her extra bargaining power, in which case the supplier is 'holding up' the buyer.

Experiment Design

We model the hold-up problem as a two-player, three-stage game with player 1 the buyer and player 2 the supplier. The buyer moves first and decides whether or not to make an investment of V which if prices do not change, will increase her profits by P>V (representing a net saving of P -V). If the investment is made, the supplier then moves second and decides whether to raise her price by R or keep it the same. If the supplier raises her price, the buyer is third to move and decides whether to keep the same supplier or change to a different supplier.

Payoffs represent utility and are 0 to both buyer and supplier if the investment is not made. If the buyer makes the investment, the payoffs are P - V to the buyer and 0 to the supplier, provided the supplier does not raise prices. If the supplier raises prices by R, the payoffs are now P - V - R to the buyer and R to the supplier, provided the buyer does not change suppliers. If the buyer changes suppliers, the payoffs are -V to the buyer (equating to the loss of the original investment) and -B to the supplier (a penalty reflecting loss of business).

Payoffs: (Buyer, Supplier)

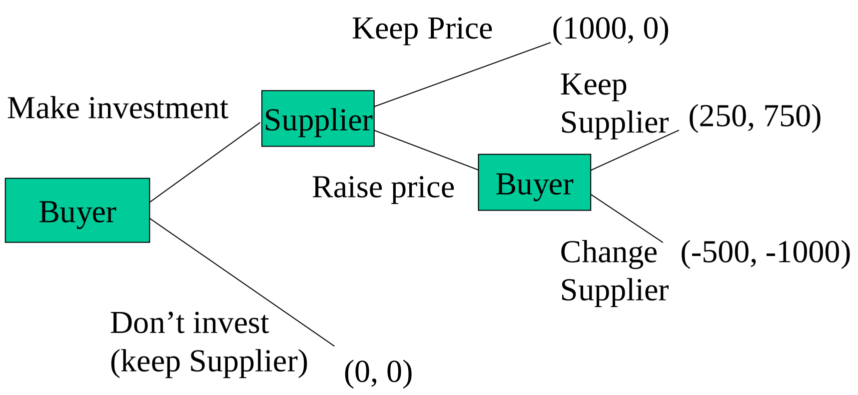


Buyer's investment costs V – only useful for that supplier.
Increases buyer's profits by P (net P - V).
Supplier can raise price by R.
Loss of business costs supplier B.

Students play 10 -20 rounds, consisting of 2 treatments of 5-10 rounds each, in random pairings with fixed roles as buyer or supplier. The parameters P, R and B are the same in both treatments but the cost to the buyer of making the investment is increased from V_1 in the first treatment to V_2 in the second ($P>V_1, V_2$) such that $P - V_1 - R > 0$ and $P - V_2 - R < 0$; this is the buyer's payoff from keeping the same supplier in the 1 stage sub-game that is reached if the buyer invests and the supplier raises her price.

The payoffs used are generated by setting P = 1500, R = 750, B = 1000, $V_1 = 500$ and $V_2 = 1000$.

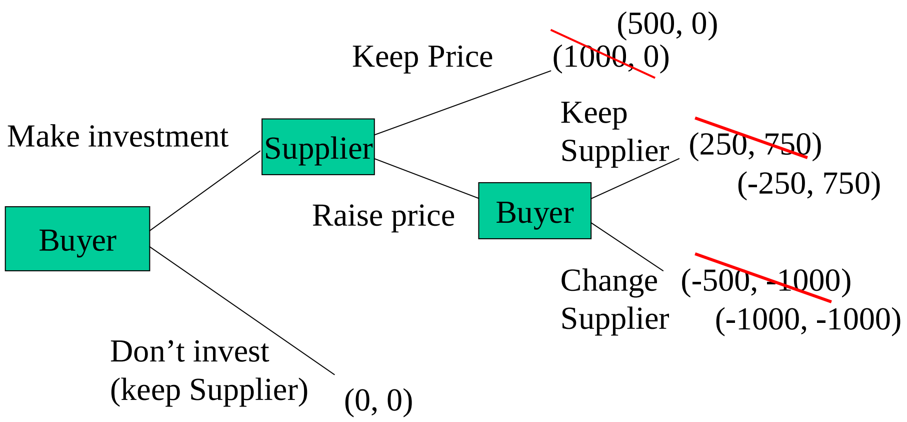
Part 1 Payoffs: (Buyer, Supplier)



Buyer’s investment costs 500 – only useful for that supplier.
Saves buyer 1500 (net 1000).
Supplier can raise price by 750.

Applying backward induction to the part 1 game, the buyer prefers 250 to -500 so she keeps the same supplier. The supplier prefers 750 to 0 so she raises her price. The buyer prefers 250 to 0 so she makes the investment. The payoffs are 250 to the buyer and 750 to the supplier. The investment is made and an efficient outcome is reached. The purpose of this first part of the experiment is that it gives students the opportunity to learn that it is optimal for the buyer to accept the price decrease. Hence it is pays for the supplier to hold up the buyer. The hold-up problem arises, but it does not lead to inefficiency.

Part 2 Payoffs: (Buyer, Supplier)



Investment now costs 1000 – potential savings 500.

In the part 2 game, again by backward induction, the buyer prefers –250 to -1000 so she keeps the same supplier. The supplier prefers 750 to 0 so she raises her price. The buyer prefers 0 to -250 so she does not make the investment. The payoffs are 0 to the buyer and 0 to the supplier; the investment is not made. Having learned in the first part that the supplier will hold up the buyer, the buyer will now hesitate and (if rational) not make the investment. In the second part the hold-up problem leads to an economic inefficiency.

Game Theory, Non-credible threats and Subgame Perfection

In solving the above games we have determined the subgame perfect equilibrium by backward induction. In a game theoretic lecture one would like to add that the game has other (pure strategy) Nash equilibria as well. This is most easily seen by looking at the normal form representation of the game. The supplier has two choices at his single decision node and hence two strategies, namely to keep or to raise the price.[2] The buyer has two choices at each of his decision nodes and hence four strategies corresponding to the choice possibilities at his decision nodes. These are: "invest" at his first node and "keep" at his second, "invest" at his first node and "switch" at his second, "not invest" at his first node and "keep" at his second, and "not invest" at his first node and "switch" at his second. It is natural to combine the last two strategies because they do not allow the second decision node to be reached. However, von Neumann and Morgenstern did not do so and so we won't either.[3] We thus obtain the following normal form representation of our two games.

	keep	raise
(invest, keep)	(1000, 0)	**(250,750)** *
(invest, switch)	(1000, 0) *	(-500, -1000)
(not invest, keep)	(0, 0)	(0, 0)
(not invest, switch)	(0, 0)	(0, 0)

	keep	raise
(invest, keep)	(500, 0)	(-250,750)
(invest, switch)	(500, 0) *	(-1000, -1000)
(not invest, keep)	(0, 0)	**(0, 0)** *
(not invest, switch)	(0, 0)	**(0, 0)** *

In these tables we give first the payoffs for the buyer and then for the supplier. For instance, if the buyer plays the strategy (invest, switch) and the supplier "keep", the investment will first be made, the supplier will keep the price and the payoffs are (1000, 0) or (500,0). The choice of "switch" in the buyer's strategy only matters for the payoff when the supplier raises the price.

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2 For the game-theoretic terminology see Osborne (2004). Since the games are of perfect information we can ignore the distinction between information sets and decision nodes.
3 One can interpret the choice at an unreached decision node as a "plan B" which the player follows if he had made an error at the first decision node and accidentally chose "invest". This interpretation underlies Selten's (1975) notion of a perfect equilibrium, often called "trembling hand" equilibrium.

The pure-strategy Nash equilibria of the games are indicated by an asterisk and the subgame-perfect equilibria are indicated by having the payoffs in bold. In the first game ((invest, keep), raise) is a subgame perfect equilibrium, in the second ((not invest, keep), raise) and ((not invest, switch), raise). In both games ((invest, switch), keep) is, however, also a Nash equilibrium: If the supplier believes that his opponent invests and then switches if the price is raised, he is better off not to raise the price. If the buyer believes that the opponent will not raise his price, it is equally optimal to keep or switch the supplier after a price change because the situation never arises. Thus both players behave optimally given the behaviour of the opponent, as required for a Nash-equilibrium. The problem with these equilibria, as identified by Schelling (1960), is that they are based on "non-credible" threats. The Buyer would like to make them at the beginning of the game and if he could commit himself to these actions, he would do so. However, if a price raise actually occurs, it is optimal for him to stay with the supplier and he will do so if he is rational and if no commitment possibility (which should be modelled explicitly in the game) exists. Selten (1965), in explicit reference to Schelling (1960), defines the notion of a subgame perfect equilibrium point such that it rules out equilibria based on such non-credible threats.

Experimental procedure

Non-computerized

Start by dividing the students into an even number of teams, seated at tables, with roughly the same number of students on each team and exactly the same number of teams in each half of the room; it helps if you have a room that naturally divides itself in two, such as a lecture theatre or computer room with a central gangway. Each team will be a single decision-maker in the experiment (Buyer or Supplier) and the members of the team will agree amongst themselves which decisions to take.[4] The teams in one half of the room will be Buyers and the teams in the other half of the room will be Suppliers. Good results can be obtained with about 20 teams (10 Buyers and 10 Suppliers); any fewer and the random matching will be less effective because the teams will play each other more than once, significantly more and it becomes too unwieldy and time-consuming to distribute and collect the decision sheets and enter the results in the summary spreadsheet.

As soon as the teams are seated, you need to decide on an order in which you will visit each team in turn, Buyer teams first, then Supplier teams, sticking to the exact same order throughout; this is important because you will need a well-established order if you are to perform the random matching quickly, accurately and anonymously.[5]

Provided there are no more than 52 teams, you can use a pack of playing cards to allocate unique names to each team. Split the pack into black cards and red cards and randomly distribute one black card to each Buyer team and one red card to each Supplier teams. Each team's name is simply the name of their card: for example, a

[4] We find that students generate better decisions and learn faster when two or more play together as a team, although there may be some noisy discussions.
[5] Anonymity of decision-making and random matching is not as critical in a teaching experiment as they would be in a research experiment; nonetheless it can significantly alter the results if anonymity is compromised.

Buyer team might be '6C' (six of clubs) and a Supplier team might be 'QH' (queen of hearts).

Hand out Part 1 Buyer record sheets to each Buyer team and Part 1 Supplier record sheets to each Supplier team and tell the teams to write their name (playing card) in the box provided.[6] Explain that the teams will need to write this same name on their decision sheets. It is important that the teams keep their names private, particularly from their opponents in the other half of the room.

Hand out marker pens and copies of the Part 1 instructions to each team. You might wish to use black pens for the Buyers and red pens for the Suppliers; anonymity is enhanced if the pens are all of the same general type. Allow 5 to 10 minutes for reading the instructions and answering any questions that arise.[7] If there are no questions, it is worth asking if everything is understood.[8]

Hand out decision sheets for round 1 to each Buyer team in order, taking successive sheets off the top of the pile like you would when dealing a hand of cards. Remind them to write their Buyer team name and the round number '1' on the first sheet. It is now time for the Buyers to make their first decision: invest or not invest. After all Buyers have decided, collect up the decision sheets, visiting the teams in reverse order and placing successive sheets back on the top of the pile;[9] also check that the Buyer team names and decisions have been recorded clearly.

Now comes the start of the random matching and some care is needed at this point. You take an arbitrary number N of decision sheets from the top of the pile and place them on the bottom of the pile; the analogy is with cutting a pack of cards. You must remember the value of N that you chose; you will choose different 'random' values each round, making sure that the students cannot see what you are doing. You then hand out the re-ordered decision sheets to each Supplier team in order[10]. Remind them to write their Supplier team name on the sheet. It is now time for the Suppliers to make their decision: raise price or keep it the same[11]. After all Suppliers have made their decisions, collect up the decision sheets, visiting the teams in order and ensuring that the decision sheets go back in the pile in the same order in which you handed them out; also check that the Supplier team names and decisions have been recorded clearly.

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6 Don't leave the photocopying and purchasing of experimental materials until 10 minutes before the class is due to start!

7 If you have a high percentage of students for whom English is not a first language, it will speed up the class if you email or circulate the Part 1 instructions to the students in advance.

8 The instructions are intended to be self-explanatory but students occasionally ask for clarification, so we recommend that you too read the instructions beforehand!

9 The idea is to re-trace your steps and re-construct the original ordering of the pile of decision sheets. You may prefer always to visit the teams in the same ‘forwards’ order, in which case you will need to add successive sheets to the bottom of the pile when taking them back. It is a matter of personal taste what method you use.

10 This random matching procedure may sound complicated but the idea is to be able to hand out and collect up the decision sheets in the shortest possible time.

11 If the Buyer has decided not to invest, the Supplier has no decision to make but you may still wish to ask the Supplier to indicate whether or not she would have raised her price.

In order to return each decision sheet to the correct Buyer team, you must restore the original order by taking N sheets from the bottom of the pile and placing them on the top of the pile. Now you can visit each Buyer team in order and hand out the sheets. You should ask each team to verify that they have the correct decision sheet: the Buyer team name on the sheet should be a match with their playing card.[12] It is now time for the Buyers to make their second decision: keep the same Supplier or change.[13] It is also time for the Buyers to record the outcome of the round (decisions and payoffs) on their record sheets; you should check that this has been done as you go round and collect up the decision sheets (visiting the teams in order as always). We find that students are quite competitive and they like to receive immediate feedback at the end of an experiment as to how well they have performed relative to their peers: the completed record sheets are the only means of providing this feedback.

Finally, transfer N sheets from the top of the pile to the bottom, before returning the decision sheets to the Supplier teams (in order) for the last time, asking each team to verify that they have the correct decision sheet. Check that the Suppliers record the outcome of the round (decisions and payoffs) on their record sheets.[14] If you have an assistant, they can be collecting up the decision sheets from the Suppliers and entering the decisions from round 1 into the summary spreadsheet, leaving you free to concentrate on round 2.[15]

Proceed as above through rounds 2 to 5.

After completing round 5, explain that the Buyer is about to face changed payoffs because the cost of making the investment has increased. Hand out copies of the Part 2 instructions to each team. Allow 2 or 3 minutes for reading the instructions and answering questions. Then proceed as above with rounds 6 to 10.

It is now time to hand out the questionnaire, which the students must complete before you start any discussion of the results. The questionnaire will also keep the students busy while you enter the remaining results in the summary spreadsheet. If you are on your own, you can do a quick summary simply by asking the Supplier teams to add up how many times each of the 4 possible outcomes were reached in rounds 1 to 5 versus rounds 6 to 10 (that is, 8 numbers in all per Supplier). It adds to the enjoyment of the experiment if the students are able to see at least a summary of the results, and ideally also a graph, before the end of the class.

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[12] Don't panic if something has gone wrong and a team complains that they have received the wrong sheet: you can either (1) use the team names written on the sheets to recover the situation, or (2) repeat the round. You may prefer (2) if you care about anonymity.

[13] If the Buyer has decided not to invest, or the Supplier has decided not to raise her price, the Buyer has no second decision to make but you may still wish to ask the Buyer to indicate whether or not she would have kept the same Supplier.

[14] You may wish to sample one or two of the decision sheets from the first round and, preserving anonymity as far as possible, discuss which decisions have been made. This will make the procedure more transparent to the students, leading to decision-making that is better informed, although biased (but this is NOT a research experiment).

[15] If, however, you are running the session on your own, it is better to leave the decision sheets with the Supplier teams so that they can help you produce a summary of the results at the end. We would not recommend mixing the activities of performing the random matching and summarising the results.

Computerized (Feele Lab website)

Detailed Procedure

The computerized version of this experiment is available on the Feele Lab website. The procedure for setting up and running this experiment for the first time is as follows: (1) locate the Feele Lab homepage, (2) register your email address to obtain an experimenter's username and password, (3) log in as an experimenter, (4) create a new hold-up experiment, (5) add a default session to this experiment, (6) change some of the default configuration values, e.g. number of subjects, (7) start the session running, and (8) invite your students to log in to the session as 'subjects' while you monitor the 'View Results' screen.

To locate the Feele Lab homepage, do a Google search for the word 'feele' and click on the first link, FEELE Laboratory.

Click on the large-font link 'Lecturers: Run Experiments here' to display the Feele Website of Teaching Experiments page. There is an **Economics Network Presentation** (MS PowerPoint) in the Getting Started section which you may find helpful: right at the end of it is a series of screen-shots explaining how to register and log in as an experimenter and create your first experiment.

To register your email address, start from the Feele Website of Teaching Experiments page (see above) and click on 'Experimenter (lecturer) access'; the browser should open a new tab showing the Feele Lab Experimenter Access page. Click on the Register button [New Experimenter Registration] to bring up the Experimenter Registration page. Now enter your initials, your email address and your first and last names; your username will be emailed to you and consists of the initials you entered plus a numeric suffix. For the sake of an example, let us assume that your username is 'abc1'.

To log in as an experimenter for the first time, click on the Login Now button and enter your new username and password in the boxes provided on the Experimenter Login screen. (On subsequent occasions when you log in as an experimenter, you will need to start from the Feele Lab Experimenter Access page. You then bring up the exact same Experimenter Login screen by clicking on 'Experimenter (lecturer) access' and then on the Login button [Experimenter Login].) If you have logged in successfully, you will see a screen entitled, 'abc1 - View Experiments', where 'abc1' is your username.

To create a new hold-up experiment, click on the Add Experiment button. Set the Experiment Type to 'Holdup Problem' using the drop-down list and enter 'holdup' as the Access Suffix. (The Access Suffix is a code word of your own choosing that your students will need to know to be able to log in to your experiment.)

To add a default session to the new experiment, starting from the View Experiments screen, click on View Sessions to bring up a screen entitled 'Experiment abc1-holdup (Holdup Problem) – View Sessions'. Then click on Add Session to create session #1.

To change the default configuration values, starting from the View Sessions screen, click on Configure to bring up a screen entitled ‘Experiment abc1-holdup (Holdup Problem) - Configure Session #1’. Change the Number of Subjects’ from 2 to however many students you have; you must have an even number and you may need to have students pair up in twos or threes to share a computer if the class is large. Click on Confirm to save your changes.

To start the session running, starting from the View Sessions screen, click on Start Run; the Status of the session changes from Ready (navy blue) to Running (green). This step is important: your students won’t be able to log in if you forget to start the session running! To monitor you students as they log in, you should now click on View Results to bring up the results monitoring screen; this screen has a 10 second auto-refresh by default but you can click on Disable Refresh if it becomes annoying.

To log your students in to the running session, tell them to locate the Feele Lab homepage, as you did, by doing a Google search for the word ‘feele’ and clicking on the first link, FEELE Laboratory. They should then click on the large-font link ‘Students: Log In here’; the browser opens a new tab showing the Feele Lab Participant Access page and they then click on the Login button [Participant Login] to bring up the Participant Login screen. In order to log in to your experiment, they need to enter an Access Code, which is ‘abc1-holdup’, where ‘abc1’ is your username and ‘holdup’ is the Access Suffix that you entered when you created the experiment (see above).

Hints and Tips

Before running this experiment for the first time with real students, it is a good idea to set aside a few minutes to configure and run a short test session where you log in a couple of test subjects using multiple browser tabs and play say 2 rounds with low investment cost and 2 rounds with high investment cost, just to gain familiarity with the computer interface.

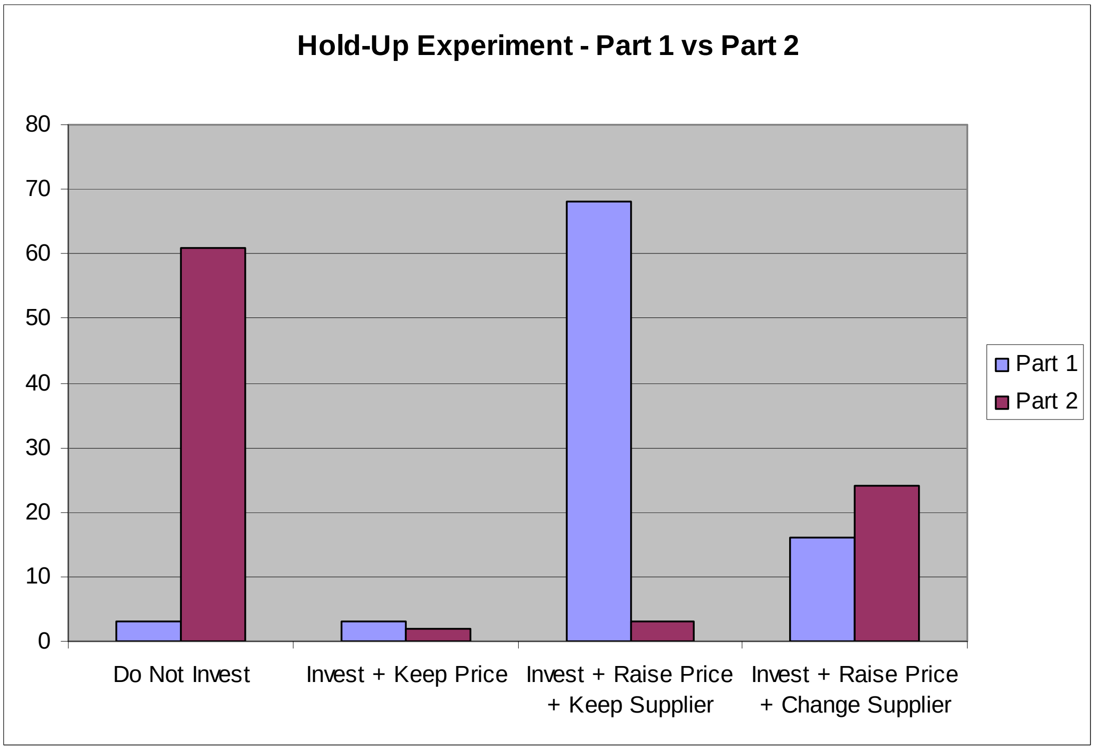
Just as with the non-computerized version of this experiment, if you have a high percentage of students for whom English is not a first language, it will speed up the class if you email or circulate the Part 1 instructions to the students in advance.

It will speed up the logging in process if you circulate hand-outs to the students explaining what to do; if you number the hand-outs beforehand, it will make it easier to count up how many students there are when configuring the software.

Some results and suggestions for classroom discussion

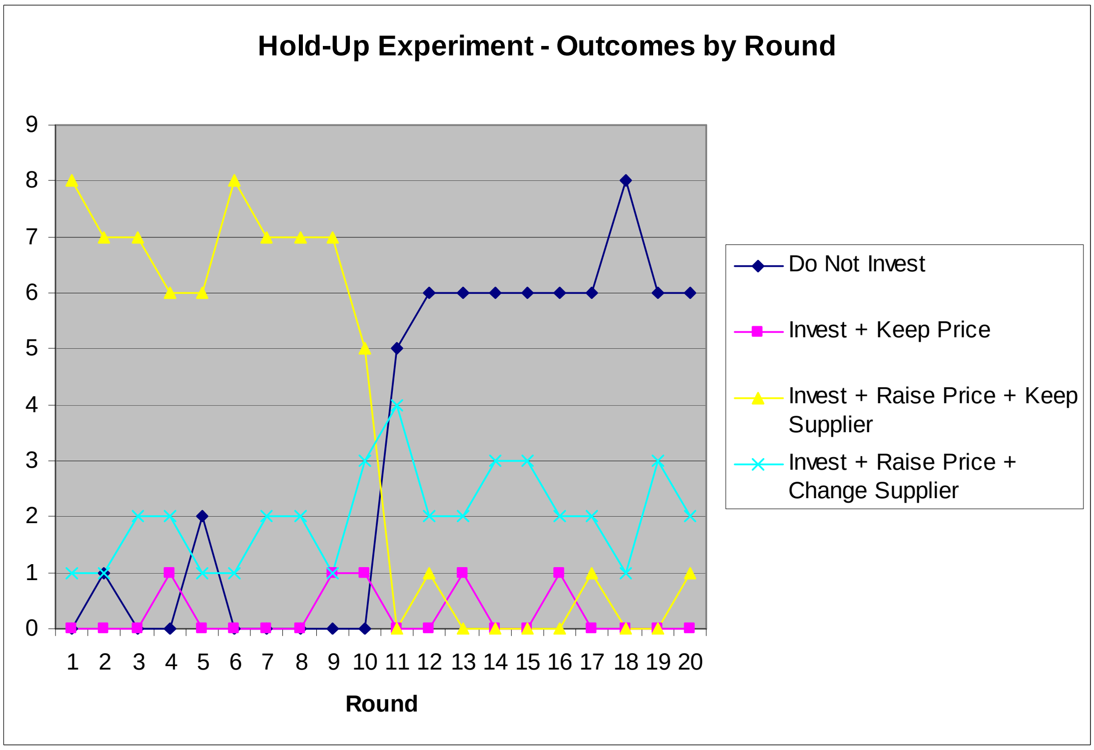
Results from a computerized session

We ran the computerized version of this experiment in 2007 with 9 (randomly matched) pairs of undergraduates over 20 rounds.



The sub-game perfect equilibrium ((invest, keep), raise) is reached on 68 occasions in part 1 (rounds 1 to 10) but only 3 occasions in part 2 (rounds 11 to 20). Conversely, the ‘do not invest’ outcome is reached on only 3 occasions in part 1 but on 61 occasions in part 2. These are the predominant outcomes. The ‘punishment’ outcome (invest, change), raise) is reached on 16 occasions in part 1 and 24 occasions in part 2. The ‘invest and keep price’ outcome is hardly reached at all, occurring only 5 times in total, 3 in part 1 and 2 in part 2.

If we look at the outcomes round by round, there appears to be a slight ‘last round’ effect in round 10, where 3 pairs reach the punishment outcome. In part 2, there are 4 rounds (14, 15, 18 and 19) in which only two of the outcomes are reached: either the Buyer does not invest or else the punishment outcome is reached. The Buyer and Supplier appear to take a different view of the Buyer’s threat to change suppliers; the Buyer would like to ‘coerce’ the Supplier into not raising her price, even though it is irrational to change suppliers because the subjects are randomly re-matched at the start of the next round.



Suggestions for classroom discussion

Is there a hold-up in part 1 of the experiment and is the outcome inefficient? How about part 2?

In part 1, the Buyer is indeed held up, but the hold-up only affects the distribution of income because the Buyer still has some residual bargaining power. The outcome is not inefficient but the Supplier's income is determined more by the Buyer's willingness to pay than by the value of the work done. We have not considered inefficiencies that arise when resources are diverted to resolve contractual disputes, e.g. legal fees.

In part 2, the Supplier has relatively greater bargaining power and the hold-up largely prevents the investment from being made; this is an inefficient outcome.

Surely the contract could specify that the work be done to a fixed price, thereby eliminating the problem?

Unfortunately it is prohibitively expensive to attempt to write and agree to a contract that anticipates every possible situation that may occur during a length project. There will always be loopholes that allow the supplier to default on the contract in subtle ways. Proving shirking in quality or effort in court can be difficult. The supplier will also be able to take advantage of unforeseeable external events.

In the case of the Soviet military, the arms manufacturers were able to cut costs by substituting goods of inferior quality. The state attempted to counter this by employing a small army of inspectors. For more complex items, such as tanks and guns, it turned out to be prohibitively expensive to monitor and correct quality during production, despite the fact that inferior quality was readily observable once the goods were delivered. A compromise was reached whereby the inspectors turned a blind eye to clear breaches of the contract, such as shortfalls in quantity and late deliveries, in return for improvements in quality; this collusion amounted to criminal deception and the individuals concerned risked punishment. It did lead to a more efficient outcome because the lowest quality items actually cost more to produce than they were worth to the army.

With Fisher versus GM, however, the hold-up came about because of a large and wholly unexpected increase in the demand for closed metal bodies in the early 1920s. The contract was cost-plus and specified that GM pay Fisher 17% over and above any non-capital costs. This gave Fisher a perverse incentive to build new plants further away from GM's plants, so that they could profit from the transportation costs. The solution was a merger between GM and Fisher.

Other examples of hold-ups.

Eurotunnel disputes.

The Eurotunnel development is a more complex example of a hold-up resulting from several unforeseen external events. The contractor TML was working to a cost-plus contract to bore the tunnel and a fixed price contract to supply fixtures and fittings.

TML encountered unexpected geological problems from the outset and this, following late signing of the treaty, meant that it soon fell behind its targets, incurring a large financial penalty and leading to a dispute with the customer, Eurotunnel. The contract stipulated that work should continue while the dispute went to arbitration but TML was unwilling to sink more money into it. Eurotunnel too was now in trouble because it needed to demonstrate progress to its bankers. The banks (possibly missing an opportunity for a hold-up of their own?) brokered an agreement between the two parties that re-wrote parts of the cost-plus contract, allowing work to re-start.

The hold-up followed two unexpected developments which greatly increased the cost to TML of the fixed price contract. Firstly, the fire regulations were exceptionally demanding and TML had to re-design the train doors to be larger than normal, leading to significant knock-on costs that could not have been anticipated. Secondly, the railways demanded to be able to run three times the expected number of trains per hour, necessitating double the electrical power.

The dispute became increasingly acrimonious. TML went on a go-slow, which was very damaging to Eurotunnel, as any delay involved huge loss of potential revenue. Eurotunnel countered by delaying payments in an attempt to drive TML into negative cash flow. The negative cash flow, and the threat of liquidated damages, caused TML some pain, more so because the UK construction industry was in recession at the time. However Eurotunnel was under the greater pressure and in the end it was obliged to give ground.

Training and Skills Shortages.

When a new employee joins a company, they frequently require training before they are fully productive. The training may be specific to the particular firm or it may be more generally useful, usually in a related field, such as if the worker were to leave to join a competitor.

If the employee pays for the training in specific skills for that firm, by working for reduced wages while on probation, the firm has an incentive to hold up the worker when the probationary period is over, by offering them a different contract on less favourable terms; the company may also cherry-pick the best workers. The worker has very little power and can be exploited. The company benefits in the short term but, if it gets a very bad reputation, it may suffer from adverse selection, being unable to recruit good workers. Both parties may benefit from collective bargaining.

If, however, the company pays for the training, it is now the worker who has an incentive to hold up the company, by threatening to leave and work for a competitor. The company may counter this by making ex-employees sign a contract that they will not work for a direct competitor for a certain period of time. The contract may or may not be enforceable.

In both cases, the one paying for the training would not reap the rewards if the relationship is severed. This would allow the other party to hold them up and collect some of the returns. Hence, there is a disincentive to make an investment in skills which would benefit both parties.

Car Body Design.

In the 1980s, car manufacturer used to employ in-house software departments to do car body design by writing and maintaining bespoke code in a legacy language such as FORTRAN. This software base was large, complex and wholly undocumented, making it maintainable only by the original authors. It was difficult for the company to recruit a replacement for anyone who left. Even if a company found someone with the appropriate knowledge of fluid mechanics and programming (in all likelihood poached from a very limited number of competitors), that person would still have difficulty comprehending the code. So the software department was able to hold up the company and demand high wages and obtain a high degree of job security.

The “solution” to this problem for the firm came from an unexpected direction: cartoons. It so happened that the software used to animate digital movies could also be applied to designing prototypes. At the same time commercial software such as Fluent became available to work out the aerodynamic properties of the body. Together they eliminated the need for internal software development and the car companies were able to escape from the hold-up by out-sourcing the software design to ‘Hollywood’ and other 3rd parties. The few programmers left in the design department were relegated to adapting and using software developed elsewhere. This is the exact reverse of the Fisher/GM situation, where vertical integration was seen as the solution to the problem. Here, we see a general benefit for using standardized products in preventing a hold-up problem.

Large civil engineering and public sector software projects.

Typically the contract is largely fixed price, is put out to tender and goes to the lowest bidder. The specification is vague and it is difficult for the contractor to estimate costs at the outset. The auction is highly competitive and is effectively all-pay because of the high cost of tendering. The successful contractor is left with a significant winner's curse and a strong incentive to exploit to the maximum any opportunity for hold-up. The project is complex with many changes of specification, providing an excuse for the contractor to raise prices. If the project has a fixed deadline, such as the construction of an Olympic venue, it is the customer, not the contractor, who is in the most trouble if the project is running late; the contractor is then able to make more and more outrageous demands, although there is a limit to this because ultimate failure of the project would be damaging to the contractor's reputation. The customer's last resort is to go to court but this threat is not always credible: it is time-consuming and requires expert testimony, distracting resources from the task in hand and doing nothing to recover lost time.

Punishment.

While the subgame perfect equilibrium prediction does quite well in this setting, there are sometimes a handful of buyers that switch suppliers once the price is raised, essentially punishing the suppliers. This outcome is always worse for both the buyers and the suppliers. This relates to punishment in public good games and the ultimatum game. One should definitely point out to those employing that strategy that profits are lower, but you could emphasize if the game is repeated with the same supplier or there can be reputations of individual buyers, then the strategy of punishment can indeed be viable.

Conclusion.

We have presented both a hand run and computerized classroom experiment that demonstrates the hold-up problem to students. While simple in structure, it conveys the key ingredients of a core industrial organization problem with many real-life examples. In our experience this experiment will help students understand key concepts in courses of Industrial Organization, Game Theory, and Law and Economics.

We have suggested ways to use the experiment in class. We suggested further questions and answers and more motivating examples for the hold up problem. For a game theory class we suggest to combine this experiment, where subgame perfection tend to perform well when students can the game tree, with games like the ultimatum game, where the subgame perfect equilibrium is hardly ever observed.

Our experiment is based on a very simple perfect information game with a unique subgame perfect equilibrium. In richer models of the hold up problem one will have to discuss additional concepts like renegotiation proofness. Further developments for classroom experiments could address the behaviour in such richer models.

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