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# Patents and R&D: A Classroom Experiment

*Amy McCormick Diduch*

## Abstract

Public policy towards patents has assumed a robust positive relationship between the strength of patent protection and the level of innovative research effort even though economic theory and empirical evidence suggest that the impact of patents on research varies considerably by industry. This classroom experiment provides students with an introduction to two competing models of the impact of patents on R&D: the 'winner-take-all' model contains incentives for excessive research effort and the 'knowledge spillover' model contains incentives for free riding. Class discussion explores potential changes to current patent policy and policy alternatives for stimulating R&D.

## Introduction

Growth theory asserts that an economy's long run rate of economic growth is strongly related to its rate of productivity growth. Productivity growth, in turn, is determined in part by innovation and technological progress. Thus, governments interested in promoting long run economic growth choose policies that encourage innovation. Granting patents to innovators has long been assumed to be one important part of the policy menu. However, economic theory and empirical evidence indicate that patent protection does not always provide incentives for optimal levels of research and development. Patent law, industry structure and externalities associated with knowledge may result in too much or too little research effort.

This paper describes a classroom experiment that allows students to determine research effort in response to two different incentive structures: a 'winner-take-all' system and one in which there are extensive knowledge externalities. In the 'winner-take-all' structure, firms typically engage in too much duplicative research and the total research expenditures exceed the financial rewards from the patent. In the externalities structure, firms are tempted to free ride on the research efforts of others and outside intervention is sometimes required to spur research effort. In general, the experiment makes the point that a one-size-fits-all patent policy is unlikely be socially optimal. Class discussion centres on the remedies available, including changes to patent law, direct subsidies of research, removal of barriers to collaborative research, or the granting of prizes. This experiment is particularly well suited to courses in intermediate microeconomics, industrial organisation, and experimental economics or courses with a public goods policy focus, and could be combined with a research project on R&D efforts in specific industries. A 50-minute class provides enough time for the experiment and brief discussion. A 75-minute class allows for greater attention to the incentive structure of the experiment and equilibrium outcomes.

Why should undergraduate economics courses give greater attention to patents? Several recent controversies have raised questions about U.S. and world patent policies. Pharmaceutical, software and music firms from industrialised countries lobbied hard for the inclusion of strict intellectual property protection in the 1994 Uruguay round of the General Agreement on Tariffs and Trade. The TRIPS agreement (or Treaty on Trade-Related Aspects of Intellectual Property Rights) provided for universal patent recognition and a standardised 20 years of patent protection across countries (Correa, 2000). Although the agreement allowed countries to adopt measures necessary to protect public health, 39 pharmaceutical companies filed suit against South Africa in 1998 to prevent the importation or production of generic copies of patent-protected AIDS drugs. World outrage was captured by a March 2001 headline in the *Jakarta Post*: 'Millions die of AIDS just to respect patent rights'. The public relations disaster that followed caused the companies to drop the lawsuit in April of 2001 and resulted in a WTO agreement allowing developing countries an additional 15-year grace period to implement common patent policies.

Biotechnology provides other important dilemmas for patent law. Developing countries could benefit significantly from innovations that improve agricultural productivity but agricultural research tends to be underfunded due to large spillover effects. Yet one solution to that problem – creating intellectual property rights for genetically modified organisms – has created substantial problems for poor farmers who cannot reuse seeds from the harvest (World Bank, 2007). Policy makers must search for solutions that maintain incentives for R&D while allowing poor farmers access to new discoveries.

## Patents and R&D: theory and empirical research

Policy makers have always recognised the tradeoffs inherent in the granting of patents. In exchange for public disclosure of the innovation (so that other researchers may build on the discovery), patent holders are granted monopoly rights to the use of the innovation for a fixed period of time. The size of the welfare loss varies with both the length and breadth of the patent. A patent can confer broad protections – to prevent the use of closely related innovations without the permission of the patent holder – or narrow protections, which allow for a greater degree of 'me-too' inventions. As long as length and breadth are carefully chosen, the welfare loss from monopoly pricing and output levels can be smaller than the gains from higher levels of innovation. Policy choices are complicated by the fact that knowledge has the characteristics of a public good. It is non-rival in use and can be largely non-excludable, particularly in the absence of intellectual property protection. Although societies benefit from a wide dissemination of knowledge, firms that first produce knowledge may find it difficult to fully appropriate the benefits of it, as other firms copy their advances and compete against them in the marketplace.

Patents are an imperfect means of achieving the twin goals of increased research and the dissemination of knowledge. As Kenneth Arrow (1962) noted, 'No amount of legal protection can make a thoroughly appropriable commodity out of something so intangible as information.' Thus, Arrow predicted a downward bias in inventive activity, particularly for basic research. Conversely, to the extent that a firm is able to appropriate the use of its research, Arrow argued that the information itself would be underutilised.

Does the public goods nature of knowledge necessarily imply a downward bias in research activity? Dasgupta (1988) argues that it does not when firms compete against each other. R&D activities offer firms opportunities to gain market share but the competition for these gains can result in excessive R&D expenditures, particularly when only one 'winner' receives a patent. This 'horse race' or 'winner-take-all' model of R&D competition demonstrates that R&D expenditures may be allocated quite inefficiently – too much effort may be spent in the pursuit of one innovation (although society can benefit from parallel lines of research).

Dasgupta agrees with Arrow that knowledge spillovers can result in too little innovation. Competing firms may engage in large amount of imitative research – particularly when a patented innovation can be 'invented around'. Imitators are likely to face lower R&D costs. Depending on the level of competition and the reward structure, it may be better for a firm to be an imitator than an innovator. Gallini (1992) shows that longer patent duration can give competing firms greater incentives to invent around a patent. Optimal patent policy is likely to provide broad protection against imitation, with patent life chosen to generate the desired return from R&D investment. However, broad patent protection can discourage research that builds on or improves previous discoveries.

What are the actual effects of patent protection? In reviewing patent research, Kremer (1998) concludes that patents result in underinvestment in R&D in general but overinvestment in copy-cat research. Levin (1986) reports the results of a survey of 130 R&D executives. These executives viewed patents to be most effective in protecting competitive advantage in the chemical industry (including pharmaceuticals). In other R&D intensive industries (such as petroleum refining, plastics, computers, communications equipment, etc.), executives ranked having a first-mover advantage and/or superior sales and service efforts ahead of patents as determinants of R&D effort. Studies focused on the impact of stronger patent rights on innovation find little connection between the two (Sakakibara and Branstetter 2001, Hall and Ziedonis 2001).

Henderson and Cockburn (1996) find evidence of substantial spillovers of knowledge in the pharmaceutical industry. Large firms appear to have more productive research programmes because they can capture some of their own knowledge externalities (through related research in other product lines) but can also take advantage of knowledge spillovers from other firms. In their estimates, spillover effects enhance the research productivity of all firms.

## Classroom experiment: set-up and instructions

This classroom experiment is designed to introduce students to the ways in which the reward of a patent may result in either too much or too little R&D effort by firms. It is fairly simple to administer (requiring only playing cards, a die and a handout for students) but illustrates both the 'winner-take-all' patent race model and the case where knowledge spillovers result in significant benefits for competing firms. It works best with classes of 8–20 students. The structure of the experiment was inspired, in part, by the patent 'horse race' example described by Roger McCain (1999), in which firms invest too much in overlapping research.

From a deck of cards, remove five cards from each suit and place in envelopes that are marked with the matching suit. (For this experiment, the exact numbers on the cards do not matter.) Make copies of the instructions for each student (included in the Appendix). Make sure you have a six-sided die handy.

Divide students into four small teams (with two to five students per team). Provide the teams with enough space for private conversation about team decisions. Give each team an envelope with cards. Carefully review all instructions for the first part of the experiment with students before beginning.





### *The 'winner-take-all' model of patents*

Each team must decide how much research effort to put into the pursuit of a patent on a cancer vaccine (worth $150 million to the winning firm). Each team can allocate up to $25 million per 'year' (in $5 million increments) for research in pursuit of this patent. Research decisions are indicated by placing 0–5 cards in an envelope; since each card represents $5 million of research effort, card choice indicates research efforts of $0, $5m, $10m, $15m, $20m or $25m. These envelopes are collected by the instructor once all teams have made their decisions. Money not spent on research in any given year does not affect the research budget in subsequent years: the annual research budget always has a $25 million maximum.

After the teams have submitted their research decisions, the instructor removes the cards from the envelopes (taking care not to reveal any one team's decision) and counts all of the cards. The instructor records this number and announces it to the teams. Payoffs in this experiment are uncertain and are conveyed to students through use of a table on the student handout.

- A minimum amount of research effort must take place before a discovery is possible. A discovery is made (and a patent awarded) only if the teams have contributed a total of at least five cards (or $25 million in research expenditures). If fewer than five cards are contributed, the instructor returns the cards to their envelopes and then to the teams. The second research 'year' begins.

- The probability of a patent award increases with the total amount of research effort. When 5–11 cards are submitted, the instructor must roll a 1 or 2 on the die for a patent to be awarded. When 12–16 cards are submitted, the instructor must roll a 1, 2 or 3. When 17 or more cards are submitted, the instructor must roll a 1, 2, 3 or 4.

- If the roll of the die determines that a discovery has been made (and a patent needs to be awarded), the instructor must now determine which team wins the patent. She or he should shuffle the cards that were submitted and randomly select one of the cards. The suit of the card determines the patent winner. The instructor should ask teams to sum their research expenditures and winnings (for the team that won the patent). The cards are placed in their respective envelopes and returned to the teams.

- *If there is no winner* (as indicated by the roll of the die), the cards are returned to the teams and they must decide how much to invest in additional research for the next year. Each team can again choose to spend from $0 to $25 million (or 0–5 cards). Competition for this cancer vaccine patent continues in the same manner until a patent is awarded.

- After the first patent is awarded, the instructor allows the teams to begin research on a second (entirely new) vaccine. The instructor should remind the teams to record their decisions in the section marked 'patent #2' on the instruction sheet. The teams can again choose from 0–5 cards ($0 to $25 million) of research effort.
- If patents are awarded in the first rounds both times, the instructor may want run the 'winner-take-all' patent race a third time.

### *The spillover model of patents*

Before discussing the results from the first part of the experiment, the instructor should now run the second part of the experiment. Here, the patent is still worth $150 million. However, firms that do not receive the patent now receive benefits worth $130 million after the patent has been awarded. The game proceeds exactly as described above.

Research effort may decline dramatically in the spillover section of the experiment. It is possible that total research expenditures will fall below the $25 million minimum and no discovery can be made. Teams with higher initial research expenditures frequently reduce their expenditures significantly in subsequent rounds as they punish the free-riding attempts of the competing teams. If the teams are unable to generate at least $25 million in expenditures after several attempts, the instructor may choose to allow the teams 5–10 minutes to communicate with each other or may announce a government-sponsored prize of $30–50 million to be added to the profits of the firm that makes the discovery (therefore increasing the value of the patent to $180–$200 million). One or two rounds are usually sufficient to make the point about decreased research effort in the 'spillover' model.

### *Class discussion: winner-take-all patent race*

Generally, an instructor will want to start by discussing what happened. First, in the 'winner-take-all' patent race, did total research expenditures equal or exceed the value of the patent in any of the patent races? Does the reward structure in this round encourage high levels of research expenditure? What strategies did individual teams use? What strategies did they expect other teams to use?

The experimental results illustrate several important points about winner-take-all patent races. First, any one firm may face a strong incentive to increase its level of R&D (particularly if the extra research expenditure crosses a 'tipping point' of 5, 12 or 17 cards). Second, if firms could cooperate on R&D, they would choose a much





**Table 1:** Expected value of your research expenditure choice

| Total cards played by others | Number of cards played by you 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 0 | 0.0 | –5.0 | –10.0 | –15.0 | –20.0 | 25.0 |
| 1 | 0.0 | –5.0 | –10.0 | –15.0 | 20.0 | 16.7 |
| 2 | 0.0 | –5.0 | –10.0 | 15.0 | 13.3 | 10.7 |
| 3 | 0.0 | –5.0 | 10.0 | 10.0 | 8.6 | 6.3 |
| 4 | 0.0 | 5.0 | 6.7 | 6.4 | 4.8 | 2.8 |
| 5 | 0.0 | 3.3 | 4.3 | 3.7 | 2.0 | 0.0 |
| 6 | 0.0 | 2.1 | 2.5 | 1.7 | –0.2 | –2.3 |
| 7 | 0.0 | 1.2 | 1.1 | 0.0 | –2.0 | 6.3 |
| 8 | 0.0 | 0.6 | 0.0 | –1.4 | 5.0 | 3.8 |
| 9 | 0.0 | 0.0 | –0.9 | 3.8 | 3.1 | 1.8 |
| 10 | 0.0 | –0.5 | 2.5 | 2.3 | 1.4 | 0.0 |
| 11 | 0.0 | 1.3 | 1.5 | 1.1 | 0.0 | –1.6 |
| 12 | 0.0 | 0.8 | 0.7 | 0.0 | –1.3 | 4.4 |
| 13 | 0.0 | 0.4 | 0.0 | –0.9 | 3.5 | 2.8 |
| 14 | 0.0 | 0.0 | –0.6 | 2.6 | 2.2 | 1.3 |
| 15 | 0.0 | –0.3 | 1.8 | 1.7 | 1.1 | 0.0 |

Expected value = [(Probability of award)*(Probability that you win)*(Value of patent)] – Research expenditure

lower level of expenditures. To understand these points, it is helpful to calculate the expected value of R&D expenditures at the 'tipping points' of the game. With this information (provided in Tables 1 and 2 for the winner-take-all races) students can compare three outcomes: the experimental results from their own game play, their 'best response' given the contributions of other teams, and the joint profit-maximising choice.

Table 1 reports expected value calculations for the 'winner-take-all' patent race. For any one team's choice of 0–5 cards (across the top row), the table reports the expected value of that choice conditional on the total number of cards contributed by the other teams. The expected value for a team is calculated as {(probability that a patent is awarded) * (probability that your team wins the patent) * (value of the patent)} – research expenditure of the team, and ranges from –$20 million to $25 million. The probability that the patent is awarded increases at discrete intervals as the total number of cards contributed hits certain values (5, 12, and 17). Any one team's likelihood of winning a patent depends on its own research effort relative to the effort of other teams. Only the winning team benefits from the patent award. All other teams have negative earnings for the round.

Optimal strategy is complex and a 50-minute class will probably not provide enough time to thoroughly discuss Nash equilibria. (To determine whether any given card combination is an equilibrium, you must consider each of the possible plays that could generate that combination and whether any team could change its own contribution to make itself better off.) A team is best off when it chooses an intensive research strategy (five cards) and all of its opponents choose to do no research. Playing five cards is also a reasonable strategy whenever a team believes that doing so might create an increase in the probability of a patent award (i.e. when other teams play a total of seven or 12 cards). Once that 'tipping' point has been reached, however, the optimal numbers of cards played by any one team usually decreases as other teams increase their research effort.

There are several Nash equilibria in this game. To help students understand how to find one, start by examining a combination that is not: all teams play five cards. For this combination, the expected value of the patent is zero. Any team could increase its expected reward by reducing research effort. When the total number of cards played exceeds 17, any additional research expenditure does nothing to increase the probability of a discovery. When each team contributes four cards, the expected value of the patent award is –1.3. Any one team could improve its payoff by increasing research effort to five. Thus, each team contributing four cards is not an equilibrium outcome. However, all teams contributing three cards and all teams contributing two cards do result in Nash equilibria. So do combinations that result in a total of 17 cards contributed. Instructors may invite students to check their own choices in each round (and total contributions by other teams) against the expected value calculations in Table 1, asking whether they would have preferred a different level of research effort in light of the decisions made by the other teams.

What is the amount of research expenditure that maximises joint profits? In the absence of externalities, this should be the expenditure effort that maximises the probability of a discovery relative to the amount of research expenditures. Table 2 presents the joint profit calculations. When five cards are contributed (for total research expenditures of $25 million) the expected value of the research effort is 1/3 * $150 – $25 = $25 million. When 12 cards are contributed (increasing the probability of discovery to ?), the expected value is $15 million. When 17 cards are contributed (increasing the probability of discovery to 2/3), the expected value is





**Table 2:** Joint research effort

| Total cards played | Expected value of joint profits | Total cards played | Expected value of joint profits |
|---|---|---|---|
| 0 | 0 | 11 | –5 |
| 1 | 0 | 12 | 15 |
| 2 | 0 | 13 | 10 |
| 3 | 0 | 14 | 5 |
| 4 | 0 | 15 | 0 |
| 5 | 25 | 16 | –5 |
| 6 | 20 | 17 | 15 |
| 7 | 15 | 18 | 10 |
| 8 | 10 | 19 | 5 |
| 9 | 5 | 20 | 0 |
| 10 | 0 | | |

$15 million. In this experiment, marginal increases in research effort have the effect of increasing an individual firm's probability of gaining a patent but do not always increase the likelihood that a discovery is made. For example, suppose that the opposing teams have contributed a total of four cards. If your team contributes the fifth card, joint expected profits are $25 million but your own expected value is $5 million. However, you can increase the expected value of the patent for yourself by increasing your research effort by one more card (and thus increasing the total cards contributed to six). Expected joint profits are now only $20 million but you increase your own expected value to $6.7 million. In other words, what is privately optimal for one firm – increasing its research expenditures relative to competing firms – is not always optimal for the industry as a whole.

When the patent is not awarded in the first round, the classroom experiment may generate the result that total costs of research expenditures exceed the value of the patent. Even if this does not occur, the research expenditures chosen by teams routinely exceed the joint profit-maximising level of expenditure. Thus, as suggested by theory, a winner-take-all patent system has the effect of stimulating too much research effort.

Class discussion can now turn towards the inefficiency of this outcome and realistic examples (such as the competition among pharmaceutical companies to bring 'blockbuster' drugs to market while diseases with lower incidences or those more prevalent in poorer countries are virtually ignored). A winner-take-all outcome may result from patent law that provides broad protection for a long period of time. In markets where too much effort is put into duplicative research without a correspondingly higher social return, students can discuss whether it might be reasonable to reduce the breadth of patent protection. Alternatively, reducing antitrust barriers to research cooperation among firms or direct encouragement of joint research may result in more efficient levels of research.

### *Knowledge spillovers discussion*

In turning discussion towards the 'spillover' model, the instructor can begin by asking whether knowledge is a public good and whether the requirement to reveal the specifics of the discovery in order to obtain a patent creates positive externalities. (Instructors who have not yet discussed public goods can define the

**Table 3:** Expected value of research expenditure with spillover effects

| Total cards played by others | Number of cards played by you: 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 0 | 0.0 | –5.0 | –10.0 | –15.0 | –20.0 | 25.0 |
| 1 | 0.0 | –5.0 | –10.0 | –15.0 | 28.7 | 23.9 |
| 2 | 0.0 | –5.0 | –10.0 | 32.3 | 27.8 | 23.1 |
| 3 | 0.0 | –5.0 | 36.0 | 31.7 | 27.1 | 17.1 |
| 4 | 0.0 | 39.7 | 35.6 | 31.2 | 26.7 | 22.0 |
| 5 | 43.3 | 39.4 | 35.2 | 30.8 | 26.3 | 21.7 |
| 6 | 43.3 | 33.1 | 35.0 | 30.6 | 26.0 | 21.4 |
| 7 | 43.3 | 39.2 | 34.8 | 30.3 | 25.8 | 44.2 |
| 8 | 43.3 | 39.1 | 34.7 | 30.1 | 48.3 | 43.8 |
| 9 | 43.3 | 39.0 | 34.5 | 52.5 | 48.1 | 43.6 |
| 10 | 43.3 | 38.9 | 56.7 | 52.3 | 47.9 | 43.3 |
| 11 | 43.3 | 60.8 | 56.5 | 52.1 | 47.7 | 43.1 |
| 12 | 65.0 | 60.8 | 56.4 | 52.0 | 47.5 | 65.6 |
| 13 | 65.0 | 60.7 | 56.3 | 51.9 | 69.8 | 65.4 |
| 14 | 65.0 | 60.7 | 56.3 | 74.0 | 69.6 | 65.2 |
| 15 | 65.0 | 60.6 | 78.2 | 73.9 | 69.5 | 65.0 |

Expected value with spillovers = Probability of award * [(Probability you win * value of patent) + (Probability other team wins * value of spillover)] – Research expenditure





terms 'non-rival' and 'non-excludable' and ask students for examples of goods that fit these categories.) Typically, a good bit of free-riding occurs in this round: at least one team decides to contribute only one or even zero cards. When free-riding is prevalent, how do firms profit from discoveries?

Tables 3 and 4 report the individual and joint expected value calculations for the 'knowledge spillover' version. Knowledge spillovers increase the joint profit-maximising level of research expenditure. The total value of a discovery is now $540 million ($150 to the winning firm and $130 to each of the other firms). For a research effort of $25 million (five cards), the joint expected value of research is 1/3 * $540 – $25 = $155. For a research effort of 12 cards, the expected value is ½ * $540 – $60 = $210. For a research effort of 17 cards, the expected value is 2/3 * $540 – $85 = $275. Any one firm's research effort which increases the probability of a discovery increases the expected gain for all firms.

Will the actual research expenditure increase now that spillovers are present? Or will free-riding reduce research effort? The shaded areas in Table 2 display the Nash equilibria card combinations for this round. One set of equilibria centres around card combinations that total 17. The best possible payoff for our hypothetical Team A is to play two cards while each other team plays five cards. This is a Nash equilibrium: each of the other teams has an expected value of $65.6 and cannot increase this value with any change in card allocation. Thus, if you think all other teams will contribute five cards, you should contribute two. However, if all teams

**Table 4:** Joint research effort/spillover effects

| Total cards played | Expected value of joint profits | Total cards played | Expected value of joint profits |
|---|---|---|---|
| 0 | 0 | 11 | 125 |
| 1 | 0 | 12 | 210 |
| 2 | 0 | 13 | 205 |
| 3 | 0 | 14 | 200 |
| 4 | 0 | 15 | 195 |
| 5 | 155 | 16 | 190 |
| 6 | 150 | 17 | 275 |
| 7 | 145 | 18 | 270 |
| 8 | 140 | 19 | 265 |
| 9 | 135 | 20 | 260 |
| 10 | 130 | | |

think the way you do, they will rationally decrease their card contributions. A second set of Nash equilibria centres around card combinations that total 12. Again, you are better off being the low contributor in this round: you would prefer to contribute one card while the other teams together contribute a total of 11. Although multiple Nash equilibria do exist and include combinations with five cards contributed, each team has a strong incentive to free ride on the hoped-for contributions of other teams. Ultimately, while the firms in this section of the experiment do benefit more from engaging in research, any one firm can still gain significant profit by being an 'imitator' rather than an innovator.

When the reward of a patent fails to encourage enough research effort, patent policy might be changed to increase the breadth of patents. However, this change would reduce the spillover effects (and thus public benefits) of the patent. Class discussion can turn to other options for encouraging research effort (such as government subsidies or prizes offered by private foundations) and whether these options provide significantly greater public benefits relative to costs. Discussion can also cover industries in which firms prefer to maintain trade secrets rather than file for patents (where reverse engineering is difficult) and industries in which firms rely on gaining market share quickly, knowing that other firms will make use of the knowledge revealed by the patent.

## Concluding thoughts

This experiment provides a springboard for classroom discussion of the effects of patents on research effort under two different incentive structures. In my experience, the 'winner-take-all' set-up consistently results in too much research effort and easily promotes discussion of the possibility that the monopoly power granted by patent protection can have more costs than benefits from society's point of view. The 'spillover' set-up provides a nice illustration of the public goods aspects of knowledge and suggests that patent protection might not be enough to encourage some types of research and development. Therefore, the standardisation of patent law in WTO countries is unlikely to result in significant public benefits from increased research effort.

I have enjoyed using this experiment in several different classroom settings: as part of an intermediate microeconomics course (following coverage of monopoly), as part of a summer seminar on experimental economics and science policy at the National Youth Science Camp and as part of an experimental economics course. The experiment and discussion encourage deeper thinking about an important policy issue that does not get significant coverage in most introductory or intermediate economics textbooks.





## Appendix: Student handout

## R&D decisions in pursuit of a patent

### *Winner-take-all patent*

You are the CEO of a pharmaceutical company. You have decided to pursue a patent on a new cancer vaccine worth an estimated $150 m to your company. The vaccine is still under development; to gain the patent, you must devote substantial research money to the project. Researchers at three other companies are also working on this vaccine. The likelihood that some company will make the breakthrough discovery increases with the total amount of money devoted to research. Ultimately, only one company benefits from the patent. If your company is successful, you receive the patent and the other companies receive nothing. If another company is awarded the patent first, you receive nothing for your research efforts.

Every 'year,' your firm must decide how much effort to put into the pursuit of this valuable patent. However, you have other research programmes as well and can devote a maximum of $25 million per year to this particular line of research.

You have been given five cards, representing research expenditures. Each card represents a $5 m investment in research funding and you may select any number of cards to play. This means that in each year, a firm chooses to spend between $0 and $25 million on R&D.

Research cannot be hurried and comes with no guarantees! In each year, there is a less than 100% probability of the vaccine. The more cards contributed by all firms together (i.e. the greater the total research expenditure), the greater the likelihood that one firm will be successful.

At least 1/4 of all of the available cards must be played for a patent to be awarded. Once this threshold is passed, the leader will roll a die. *If the required number is rolled*, the vaccine is patented. The experiment leader will draw from the cards played in the round to determine which firm is the winner of the patent. *The*

**Determination of awards:**

| **Total card contributions** | **Requirement for award of patent** |
|---|---|
| Fewer than 5 cards contributed | No patent awarded |
| 5–11 cards contributed | Must roll a 1 or 2 |
| 12–16 cards contributed | Must roll a 1, 2 or 3 |
| 17+ cards contributed | Must roll a 1, 2, 3 or 4 |

*winning firm receives $150 m while all other firms receive $0.* Thus, your chance of gaining the patent depends on the number of cards you play, the number of cards played by others, and the roll of the die.

If the vaccine patent is not awarded in the first 'year' (i.e. the roll of the die indicates no award or there are too few cards played), firms proceed to the next 'year' and again need to make a decision of how much additional R&D to do in the next year, up to $25 million. Losses are cumulative; your total expenditures from all the rounds will be subtracted from any eventual patent award.

Once the vaccine is perfected and a patent awarded, your instructor may provide your firm with the opportunity to conduct research on a second and possibly a third vaccine. Since this represents a new line of research, your past research expenditures on the first vaccine do not enter into your calculations for the new vaccine.

*Winner-take-all patent competition* *Firm name:* ____________________

**Record sheet, Patent #1**

| **(a) Year** | **(b) Number of cards you play** | **(c) Total cost of cards played (=b * $5)** | **(d) Current profit or loss (winnings – cost of cards)** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| Total profit or loss, Patent #1 | | | |

Whether you won or lost the patent competition for Patent #1, you now start fresh with a new line of research and a new budget. You can still spend up to $25 million per year on R&D for this new vaccine.

**Record sheet, Patent #2**

| **(a) Year** | **(b) Number of cards you play** | **(c) Total cost of cards played (=b * $5)** | **(d) Current profit or loss (winnings – cost of cards)** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| Total profit or loss, Patent #2 | | | |





Another fresh start. You can spend up to $25 million per year for this third vaccine.

**Record sheet, Patent #3**

| **(a) Year** | **(b) Number of cards you play** | **(c) Total cost of cards played (=b * $5)** | **(d) Current profit or loss (winnings – cost of cards)** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| Total profit or loss, Patent #3 | | | |

**Total profit or loss on all winner-take-all patent competitions:** ____________

*Patents and spillover effects*

Now the rules of the game change. In each round you can play cards in hopes of winning the patent. The patent is awarded in the same way and is still worth $150 m to the winner. But once the patent is awarded, all the other firms gain important insights they can use to advance their own research. They each receive $130 m as a result.

**Record sheet, Patent #1**

| **(a) Year** | **(b) Number of cards you play** | **(c) Total cost of cards played (=b * $5)** | **(d) Current profit or loss (winnings – cost of cards)** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| Total profit or loss, Patent #1 | | | |

Whether you won or lost the patent competition for Patent #1, you now start fresh with a new line of research and a new budget. You can still spend up to $25 million per year.

**Record sheet, Patent #2**

| (a) Year | (b) Number of cards you play | (c) Total cost of cards played (=b * $5) | (d) Current profit or loss (winnings – cost of cards) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| Total profit or loss, Patent #2 | | | |

**Total profit or loss on all 'spillover effect' patent competitions:** ____________

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