Classroom experiments on technology licensing: Royalty stacking, cross-licensing and patent pools

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DISCUSSION PAPER

NHH

Institutt for foretaksøkonomi
Department of Business and Management Science

FOR 3/2021
ISSN: 1500-4066
February 2021

Classroom experiments on technology licensing: Royalty stacking, cross-licensing and patent pools

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Abstract

We present two classroom experiments on technology licensing. The first classroom experiment introduces the concept of royalty stacking. The students learn that non-cooperative pricing of royalties for complementary intellectual property rights leads to a double-marginalization effect. Cooperation solves the problem and is welfare improving. The second classroom experiment introduces students to cross-licensing. It shows that reciprocal royalty payments dampen competition. The classroom experiments stimulate discussions of technology licensing, intellectual property rights, different royalty structures, patent pools and technology standards. We present the experimental procedures, and suggests routes for the discussion.

Keywords: licensing, royalty stacking, cross-licensing, patent pools, classroom experiment.

JEL classification. A2, O3, L24

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1. Introduction

As technology in on the rise in today's business world, intellectual property rights become increasingly important. This is illustrated by the development of the number of granted patents over time. At the European and United States patent offices (EPO and USPTO) the number of patents roughly doubled during the last decade.[1] However, technologies protected by patents are not only used by the patent owners but also potentially by others. Hence, the increasing importance of patents in particular, and intellectual property rights (IPRs) in general, also increases the importance of licensing. In this article, we present two classroom experiments on two phenomena related to licensing.

The first classroom experiment discusses royalty stacking (see, e.g., Shapiro, 2000). The problem of royalty stacking is essentially a problem of pricing complements, dating back to Cournot (1838). It is a variant of the double (multiple) marginalization problem (see, e.g., Tirole, 1988). In the case of licensing, it emerges when producers require access to technologies protected by multiple patents with dispersed ownership. In that case, the total royalty for access to all patents is higher compared to a situation where the ownership of the required patents is concentrated.

Patents protect technologies rather than products. As many products actually combine multiple technologies, a producer often requires access to multiple patents. This is quite natural to occur as inventors stand on the shoulders of giants and often apply previous inventions to reach new discoveries. For example, according to a US government report, a typical smartphone uses from 50,000 to 250,000 patented technologies (GAO, 2013). Similar observations can be made for other products in the information technology sector (Lemley and Shapiro, 2007). And even for one specific technology, technology standards can rely on several hundred patents (Rysman and Simcoe, 2008).

Similar to the standard double-marginalization problem, royalty stacking occurs because one patent owner does not take into account the effect of its royalty choice on other patent owners. The resulting problem is not only welfare-decreasing but leads to an in-

[1]Source: PATSTAT, Spring 2021.

ferior outcome for everyone involved: IPR owners, producers and consumers. One way to solve the problem is to create a patent pool that demands only one royalty for access to the essential patents (e.g., Lerner and Tirole, 2004).

At this point, the second classroom experiment enters the picture. The second experiment is about cross-licensing, for example, in a patent pool. This experiment illustrates that when two competitors require access to each other's patents, a reciprocal royalty can be used to dampen competition between them. Cross-licensing is a common practice in a variety of industries as shown by Taylor et al. (1973) already five decades ago. Understanding cross-licensing is therefore essential for anyone working on or with technology licensing.

Both experiments can be embedded well in a discussion on licensing from a business perspective. They can also be applied for an antitrust discussion on licensing. The first experiment shows that coordination with owners of complementing IPRs can be beneficial in order to decrease transaction costs. Moreover, it is not only individually beneficial but also positive for welfare. Hence, from an antitrust perspective, coordination, e.g. by forming patent pools, is considered in principle positively. The second experiment then shows that if the owners of complementing IPRs are also competitors, the access to these assets affects the competitive situation. This is obviously important from a business perspective, but is likely to be harmful for consumers and will, hence, be scrutinized by competition authorities.

The experiments can also be used to discuss different kinds of royalties, i.e., per-unit, ad valorem or fixed payments. In principle, both problems presented by the experiments would vanish at the margin with a fixed payment. This observation is a good starting point to make the students think about the benefits and costs of (different kinds of) variable royalties. Furthermore, we use the experiments to motivate discussions on patent pools, patent thickets, technology standards and standard-essential patents.

The target courses for the experiments are innovation courses for business and economics students and courses on competition policy for business, economics and law students.

2. Royalty stacking

2.1. Procedure

The experiment takes around 60 minutes including discussions. The instructions and a list of required material can be found in the Appendix. In the experiment, a student takes the role of a patent owner that demands a royalty for access to its patent from a manufacturer. The manufacturer requires access to two patents in order to sell its product. Hence, two patent owners, i.e., students, form a pair. The manufacturer itself is passive. Its production depends on the sum of the royalties. We use a simple linear demand function $q = 12 - r_1 - r_2$, where r_i is the royalty of patent owner i in € (or another currency). Each patent owner maximizes its individual profit, which is given by $\pi_i = r_i q$.

We start by distributing the instructions (see the Appendix A.2).[2] The students are asked to read them carefully. Then, in order to match two patent owners, we recommend to print numbers on pieces of paper. In order to assign students a unique ID, we bring an "A" and a "B" version of the numbers such that A1 is matched to B1. We usually distribute the numbers among the students such that a pair sits relatively far away from one another. This impedes communication in the non-cooperative rounds, and has the side effect that students mingle and get to know each other in the cooperative round. We performed the experiment with up to 80 students, i.e., 40 groups. For even larger classes one may consider forming groups representing one decision maker.

We experienced that it is beneficial to either write the demand schedule on the blackboard or use the projector for it. After the students are done reading, it is important to explain the procedure once more and to clarify questions.

We also use the pieces of paper with the IDs as record sheets and ask students to write down their decision on the backside. After each round, they submit their decision, and we record the decisions in a prepared Excel sheet.

[2] In our main description, we focus on an execution in the classroom. In Section 4, we provide some input for online settings.

The experiment consists of two phases: the non-cooperative and cooperative phase. We usually run two rounds of the non-cooperative phase as described in the instructions. The first round is then kind of a practice round, as it helps the students to understand the set-up. A second round of the non-cooperative set-up can also be interesting, because the behavior of the students often shows some dynamics as students quickly realize the interdependence of the decisions. Students usually require around 10–15 minutes to answer the first round, and around five minutes in the second round.

In the second phase, the pair of patent owners cooperate and demand a joint royalty that is equally split. The patent owners are asked to sit together and to determine the joint royalty.

2.2. Discussion

We usually do not strictly differentiate between the procedure and discussion. After each round, we ask students for their considerations. However, we spare a discussion of the main mechanisms until all rounds are performed. Table 2.1 presents the result during one of our courses.

	Avg. sum of royalties	Avg. quantity	Avg. joint profits
Round 1: separation	7.750	4.250	32.250
Round 2: separation	8.125	3.875	30.125
Round 3: coordination	6.000	6.000	36.000

Table 2.1: Summary statistics of an exemplary realization (amounts in €).

We typically observe royalties of around 4€ in the separation rounds. There is usually some variation as some students demand less, because they realize early on that a symmetric strategy with royalties of 3€ is the cooperative solution. On the other hand, other students are thinking more about their own profits and demand a higher royalty, especially, if the paired patent owner went for the cooperative solution in the first round. In contrast, there is usually very little variation in the third round. Most of the students quickly understand that a (total) royalty of 6€ maximizes the joint profit.

We use the latter observation as a start for the discussion and ask why royalties of 3€ for each patent owner do not constitute an equilibrium in the separation case. One way to visualize it, is to show the best-response functions for patent owner 1 if patent owner 2 would choose a royalty of 3€:

r_1	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
π_1	0	8	14	18	20	20	18	14	8	0
π_2	0	24	21	18	15	12	9	6	3	0
$\pi_1 + \pi_2$	0	32	35	36	35	32	27	20	11	0

Table 2.2: Best response of patent owner 1 if patent owner 2 sets $r_2 = 3$ (amounts in €).

Table 2.2 shows that joint profits are maximized if $r_1 = 3$. However, a symmetric strategy $r_i = 3$ does not constitute an equilibrium, because if patent owner 1 expects $r_2 = 3$, then it will be profit maximizing to respond by choosing $r_1 = 4$ or $r_1 = 5$. This happens not only at the expense of the other patent owner; even worse, the negative effect on π_2 is larger than the positive effect on π_1, such that welfare decreases. By maximizing π_1, patent owner 1 exerts an externality on patent owner 2. Clearly, the same is true for patent owner 2. Patent owner 2 also maximizes its profits and exerts an externality on patent owner 1. Consequently, both set a royalty above the cooperative optimal royalty level (3€). This problem emerges because individual patent owners do not internalize the externalities, i.e., they do not take into account the negative effect of its royalty on the profit of the other patent owner.

The remaining question is then to determine the equilibrium. Table 2.3 shows that none of the patent owners has an incentive to deviate from a royalty of 4€.

r_1	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
π_1	0	7	12	15	16	15	12	7	0	0
π_2	0	28	24	20	16	12	8	4	0	0
$\pi_1 + \pi_2$	0	35	36	35	32	27	20	11	0	0

Table 2.3: Best response of patent owner 1 if patent owner 2 sets $r_2 = 4$ (amounts in €).

This observation shows that fragmented ownership of patent rights stacks individual royalties on one another. The sum of the royalties is higher compared to a situation with concentrated ownership of patent rights. Fragmented ownership creates the problem of royalty stacking.

Once the royalty-stacking problem is clarified, remedies to the problem can be discussed. First, we usually introduce the concept of patent pools. A patent pool is a consortium in which owners of complementing patents pool their patents. The pool then licenses the patent rights to pool members and external parties. It can therefore also include a form of cross-licensing. Patent pools can be discussed from a competition policy and law perspective, for example, against the background of patents that complement and substitute each other. The introduction of patent pools can also be used to talk about technology standards, as standard-essential patents by definition are complements.

Second, different royalty structures can, in theory, remedy the royalty-stacking problem. In particular, demanding a fixed fee instead of a variable royalty, would solve the production inefficiency. However, whereas that is true for the stylized environment of the experiment, there are also downsides of fixed fees. Hence, the discussion can be used to motivate or relate to a lecture discussing different fees in royalty contracts, or to a lecture on the market for innovation in more general.

Finally, we like to challenge students to think about the mechanism of double margins beyond licensing. The effects originate from the fact that the patents are complements. Whereas joint pricing of substitutes leads to higher consumer prices, joint pricing of complements leads to lower prices. Hence, joint pricing of complements does not benefit only the producers but also consumers. We highlight that the same mechanism is present in a variety of settings. Our favorite example for a business-student audience, is pricing along the vertical supply chain within organizations. Pricing inputs in the supply chain is by definition pricing of complements. This reminds students of their lectures on transfer pricing, and clarifies that the mechanism is not exclusively observed in the licensing case.

3. Cross-licensing

3.1. Procedure

The second experiment on cross-licensing will take around 60–70 minutes including discussions. The instructions can be found in Appendix A.3.

In the experiment, each student takes the role of a manufacturer. Two manufacturers are matched with one another at the start and remain matched throughout the experiment. The manufacturers compete with each other on a product market. However, they require access to technologies of a competitor. The technologies are protected by patents. Therefore, they enter into a cross-licensing agreement with a reciprocal royalty fee f per unit sold. For simplicity, we assume that the manufacturer has no additional costs (or, alternatively, only fixed costs).

The manufacturers can choose any even number between 0€ and 24€ as their price. The demand function for the two companies depends on the difference between the prices and is given by Table 3.1.

$p_1 - p_2$ (in €)	**>10**	**8**	**6**	**4**	**2**	**0**	**-2**	**-4**	**-6**	**-8**	**<-10**
q_1	0	2	4	6	8	10	12	14	16	18	20
q_2	20	18	16	14	12	10	8	6	4	2	0

Table 3.1: Demand function depending on p_1 and p_2.

The experiment starts with the distribution of the instructions and students reading them carefully. Then, we use numbered pieces of paper to match the students. It is recommended to match students that sit relatively far away from each other in order to hinder communication such that explicit cooperation does not affect the result. We performed the experiment with up to 80 students, i.e., 40 groups. As with Experiment 1, one may consider forming groups representing one decision maker for even larger classes.

Afterwards, we prepare an Excel sheet, and either write the key ingredients of the set-up on the blackboard or display them on the projector. After the students finished reading, it is important to explain the procedure once more and to clarify questions.

We again use the pieces of papers with the IDs as record sheets and ask students to write down their decision on the back. After each round, they submit their decision, and we return the pieces of paper after we entered it into our Excel sheet.

The experiment consists of two phases. In the first phase, the reciprocal fee equals $f = 2€$. In the second phase, it equals $f = 6€$. We usually run two to three rounds of phase 1, because it takes students a while to figure out the optimal strategy. Whereas the first round takes the students usually around 10–15 minutes, the other rounds take significantly less time.

We typically only run one round of phase 2. Because the set-up is very similar to phase 1, students understand the basic strategies involved, and tend to answer also rather quickly. Even though playing only one round makes a coordination on prices of 24€ theoretically more likely, students are typically still in competition mode and usually not all go for that choice.

3.2. Discussion

Similar to Experiment 1, we do not strictly differentiate between the experiment and the discussion. After each round, we ask students for their considerations, but we spare a discussion of the main mechanisms until all rounds are performed.

Table 3.2 presents the result during one of our courses.

	Average price	Average joint profits
Round 1: $f = 2$	18.875	337.000
Round 2: $f = 2$	16.250	290.000
Round 3: $f = 2$	14.250	275.000
Round 4: $f = 6$	17.375	351.000

Table 3.2: Summary statistics of an exemplary realization (amounts in €)

The equilibrium prices in phase 1 equals 14€. We typically observe that the prices in the first rounds are significantly higher, because students see quickly that cooperating and setting 24€ each is jointly optimal.

How intensely the individual rounds should be discussed, depends on the group size. In small groups, our experience shows that students sustain a higher level of cooperation. Therefore, for small classes we prefer to show that 24€ does not constitute an equilibrium directly after round 1. For larger classes, that is less of a problem, and the discussion can be delegated to the end of phase 1.

p_1	**24**	**22**	**20**	**18**	**16**	**14**
π_1	240	256	264	264	256	240
π_2	240	200	160	120	80	40
$\pi_1 + \pi_2$	480	456	424	384	336	280

Table 3.3: Best response of manufacturer 1 if manufacturer 2 sets $p_2 = 24$ (all amounts in €).

In order to show that 24€ does not constitute an equilibrium, we analyze the best response to the competitor's price of 24€. Table 3.3 shows that the best response equals a price of 18€ or 20€.

In the second and third round, the students understand the game better, and the prices converge towards the equilibrium price 14€. Table 3.4 shows that 14€ is indeed the equilibrium price.

p_1	**18**	**16**	**14**	**12**	**10**
π_1	124	136	140	136	124
π_2	180	160	140	120	100
$\pi_1 + \pi_2$	304	296	280	256	224

Table 3.4: Best response of manufacturer 1 if manufacturer 2 sets $p_2 = 14$ (all amounts in €).

In phase 2, the equilibrium price equals 22€. We usually indeed observe that the prices increase after the increase of the reciprocal fee.

We start the discussion by showing shortly with a table similar to Table 3.4 that 22€ does indeed constitute an equilibrium. After the students understand the equilibria in phase 1 and 2, we discuss why they are different. It is helpful to write down the profit function of one of the manufacturers:

$$\pi_1 = p_1 q_1(p_1, p_2) - f q_1(p_1, p_2) + f q_2(p_2, p_1). \tag{1}$$

The profit equals the revenues minus the outgoing licensing payment plus the incoming licensing payment. We often start with referring to the symmetric equilibrium, and raise the question why f affects the equilibrium prices if the incoming and outgoing licensing payments cancel each other. This puzzles many students. However, there are usually some students that understand that f matters because it affects their willingness to increase the price. The higher f is, the less they are concerned with raising the price, because the profit margin is smaller, and because, at the same time, losing own production is less problematic as the incoming licensing revenue increases stronger.

Students typically start thinking quickly 'at the margin'. At this point, looking at the first-order condition of the manufacturers may help:

$$\frac{\partial \pi_1}{\partial p_1} = \underbrace{p_1 \frac{\partial q_1(p_1,p_2)}{\partial p_1} + q_1(p_1,p_2)}_{<0} \underbrace{-f\frac{\partial q_1(p_1,p_2)}{\partial p_1}}_{>0} \underbrace{+f\frac{\partial q_2(p_2,p_1)}{\partial p_1}}_{>0} = 0. \tag{2}$$

Eq. (2) shows that the last two terms increase in f. Hence, the first part has to become even smaller (more negative), i.e., p_1 is larger. More intuitively, the equation shows that for a larger f, the latter parts – the licensing payments – become more relevant. For a larger f, the company saves outgoing licensing payments when it increases the price, and at the same time, it receives more incoming licensing payments. Hence, a larger f increases the incentives to increase the price. That the payments cancel out in equilibrium, is then a consequence of the symmetry between the manufacturers. If one wants to avoid derivatives, it is also possible to argue with plus and minus signs in Eq. (1).

The experiment illustrates how reciprocal royalty payments dampen competition, and drive up prices. As the royalty f is endogenous in a cross-licensing agreement, the patent owners have incentives to choose f relatively high, driving up prices for consumers.

The results can be used to discuss examples of such cross-licensing agreements in practice. In addition to the details of licensing contracts (OECD, 2019), standard-essential patents seem to be particularly interesting (see, e.g., Baron and Spulber, 2018). Furthermore, the relationship of licensing and antitrust concerns are of importance for future decision makers. FTC (2017) serves as a good starting point for a detailed discussion of the latter.

It is also useful to link the two experiments together. It is worthwhile to recall what we discussed in the end of the first experiment: patent pools as one potential way to resolve the royalty-stacking problem. However, patent pools often include cross-licensing agreements. Experiment 2 shows that cross-licensing in patent pools may have anti-competitive effects. This implies a potential downside of using patent pools to solve the royalty-stacking problem. Both experiments can also be used as starting points for a deeper discussion of patent thickets (see, e.g., Shapiro, 2000).

Finally, in order to highlight the importance of the mechanism beyond technology licensing, one can link to another setting where the mechanism is present. In most communication networks, network operators charge reciprocal access fees (termination fees) for consumers to access other networks. One example is the mobile phone market (see, e.g., Armstrong, 1998). Here, consumers choose their mobile network operator independently, and call other consumers regardless of their choice of network operator. When calling a participant in another network, operators charge a termination fee. These termination fees were initially set endogenously by the telecommunication companies, and led then to abusively high fees. They have later been regulated ex-ante by telecommunication authorities.

More in-depth analysis of royalty stacking can be found in, e.g., Lemley and Shapiro (2007), Rey and Salant (2012) and Schmidt (2014); more details on cross-licensing in, e.g., Katz and Shapiro (1985), Fershtman and Kamien (1992) and Jeon and Lefouili (2018). Finally, combinations of the two topics are analyzed in, e.g., Lerner and Tirole (2004) and Shapiro (2000).

4. Implementation for digital teaching

The classroom experiments are also well suited for online teaching. We have performed both experiments successfully using video telephony software. The experiment and discussion can proceed almost according to the instructions. The relevant material should be made available for download during the lecture. The easiest way of forming groups is to use the breakout rooms. Each breakout room – which can consist of just one student – represents one decision maker, and is matched with one other breakout room. In small classes, the decisions can be collected by visiting the breakout rooms. For larger classes we recommend using an additional digital survey tool, for example, Google forms. The survey should ask for the group ID and the decision. Discussions after each round take then place in the plenary session.

5. Conclusion

We presented two classroom experiments on technology licensing. The experiments are designed to engage students discussing licensing from a business perspective. The experiments can be used to discuss different kind of licensing contracts, patent pools, patent thickets, and technology standards and standard-essential patents. Furthermore, the experiments highlight the relationship between licensing and antitrust concerns. The target course for the experiments are innovation courses for business and economics students and courses on competition policy for business, economics and law students.

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A. Appendix

A.1. Required material

- Instructions (see below)
- Pairs of numbers to match groups (printed on pieces of paper)
- Excel sheet to record the results

A.2. Royalty stacking: Instructions

Instructions

In this experiment, each of you will be assigned the role of a patent owner. Two patent owners will be matched with one another at the start of the game and will remain matched throughout the game. As a patent owner, you will license your technology to a manufacturer. In order to produce, the manufacturer requires access to both of your technologies - she is not able to produce otherwise.
Both patent owners will independently set their per unit royalty. The production level of the manufacturer depends on the sum of the royalty payments and is given by:

Sum of royalties (in €)	12	11	10	9	8	7	6	5	4	3	2	1	0
Units sold	0	1	2	3	4	5	6	7	8	9	10	11	12

Your job:

- Select the per unit royalty for your technology that maximizes your profit. You make this decision at the same time as the second patent owner.
- As you only grant access to your technology, there are no additional costs. Thus, your profit is simply your royalty multiplied by the units produced by the manufacturer.
- At the end of each period, please record your per unit royalty, the number of units sold, and your profits on the record sheet provided.
- All patent owners are reading the same instructions as you are now.

A.3. Cross-licensing: Instructions

In this experiment, each of you will be assigned the role of a manufacturer. Two manufacturers will be matched with one another at the start of the game and will remain matched throughout the game.
As a manufacturer, you require access to the technology of your competitor protected by a patent. At the same time, you own a patent that protects another technology that is required for production by you and your competitor. You enter into a cross-licensing agreement, and pay each other a reciprocal per unit royalty (i.e., a royalty rate that applies for both of your technologies) of 2€.
Both of independently set your final prices independently. You are able to set one of the following prices:

Possible prices (in €)	0	2	4	6	8	10	12	14	16	18	20	22	24

Your demand depends on the difference of prices:

Your price - other's price	≥10	8	6	4	2	0	-2	-4	-6	-8	≤-10
Your quantity	0	2	4	6	8	10	12	14	16	18	20
Other's quantity	20	18	16	14	12	10	8	6	4	2	0

Your job:

- Select the price that maximizes your profit. You make this decision at the same time as the second patent owner.
- You have no production costs in addition to the royalty . Thus, your profit is given by (Your Price - 2 €) · Your Quantity + 2 € · Other's quantity
- At the end of each period, please record your price, the number of units sold, and your profits on the record sheet provided.
- All manufacturers are reading the same instructions as you are now.

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