# Optimal Licensing Policy and Market Structure

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# Contents

# 1 Introduction

A glance at the figures of licensing income reveals an interesting pattern; one observes a clear upward trend, apparently tracking economic development as measured by gross domestic product (see figure 1). This tempts to claim that compensation schemes (i.e. licensing contracts) underlying this source of revenue are highly similar across the countries considered. However, a deeper look at the statistics reveals a more diversified picture. Figure 2 not only portrays an increase of those figures, but also captures periods of sharp decline, and what is more, movement contrary to aggregate economic production. Although not a proof, this suggests that economic structure might depict a non trivial influence on the form of licensing contract prevailing in a country. To illustrate the dynamics underlying the topic of licensing further, net income stemming from it is depicted in figure 3. It becomes apparent that, on the aggregate, six European countries evolved from licensee to licensor within the last century. What is more, figure 4 implies that the predominant form of licensing contract within an economy need not be stable. From 2002 to 2006 one witnesses a strong movement in the growth rate of net licensing receipts for a mainly stable growth rate of gross domestic product. Subsequently, however, the former shows an amplified reaction to variations in economic growth. This, among other things, might indicate a switch in licensing policy to a more variable (output or revenue depending) scheme.

The study of licensing behaviour was, from an economic point of view, revolutionised by contributions originating in the field of game theory. As the name suggests, the analysis evolves around the interaction between the inventor of a technological advance (or the respective patent holder) and industry incumbents, representing potential licensees. The precise form of compensation scheme, resulting from such a licensing game, is the key element of this paper. More precisely, the work focuses on the superiority licensing policies, evaluated with view on the patentee's licensing income. Particular attention is directed towards the question of how the form of market structure affects the equilibrium outcome. To that end, various modes of competition as well as asymmetries inherent to industry and firm structure are being considered. This analysis has to my best knowledge never been conducted in this form or comprehension. Thus, it will add to the existing body of literature and provide new insight on the current state of research.

The vast amount of research on the topic of licensing brings with it that this work is equally defined by matters not addressed. Firstly, focus lies on process innovations, meaning technological advances reducing the marginal cost of production. In the present time period, those have to be interpreted in form of a broad concept, potentially encompassing more intangible assets like organisational innovations. For a treatment of product innovations, the reader may refer to, among others, Caballero-Sanz et al. (1995), Kamien et al. (1985) or Li/Wang (2010). Also the design of the optimal, i.e. licensing revenue maximising, mechanism in terms of a rather *artificial construct*, is not considered. This topic is addressed in Giebe/Wolfstetter (2008), Kamien (1992) or Kamien et al. (1992) (*chutzpah mechanism*). What is more, the paper abstracts from welfare considerations; criterion for evaluating a policy's superiority is licensing revenue generated for the patentee, and not social desirability. The latter finds treatment in Faulí-Oller/Sandonís (2002), (2003), (2006) or Erkal (2005). Further, perfect and infinite patent protection are implicitly imposed. This brings with it that the duration of the licensing contract is not seen as a strategic variable (see Antelo (2009), Gordanier/Miao (2011)). As a corollary, the possibility of imitation (Fosfuri (2000)) or spillover (Aoki (2001), Bhattacharya/Guriev (2006)) is ruled out. Concerning the agreement on conditions proper to the contract, it is assumed that all bargaining power lies in the patentee. This implies that the latter makes a take it or leave it offer to the potential licensees; hence, bargaining *per se* does not arise. An explicit consideration of those matters is for instance found in Mauleon et al. (2010), Sempere-Monerris/Vannetelbosch (2001) or Watanabe/Muto (2004).

The remainder of the paper is organised as the following. Chapter 2 discusses the standard licensing policies, namely auction, fee, royalty, as well as their combination, within a basic framework. Subsequently, section 3 and 4 elaborate on how deviations from the latter, found in product differentiation and informational asymmetries, challenge the classical results on the superiority of the various schemes.

# 2 Established Frameworks and New Results

A large portion of the results presented in this paper can be traced back to the work of Kamien and Tauman as well as Katz and Shapiro emerging during the mid 1980s. Employing a game theoretic framework in order to contribute to the ongoing research on licensing strategies they were among the first to explicitly account for the competitive interaction among the potential licensees and the patentee's ability to exploit the latter. Following their contribution, the licensing game is predominantly modelled in form of a three stage game in which the inventor takes on the role of a Stackelberg leader. This implies that he anticipates the best response function of the potential licensees and incorporates it in his optimisation problem.

Before describing the various steps of the game more precisely, a word on the nature of the industry is appropriate. In what might be called the classical framework it is commonly assumed that the potential licensees are identical and form a n-firm oligopoly producing homogeneous products under constant marginal costs. Expenditures associated with entry in the industry are assumed to exceed profits such that entry is not profitable.[1] While most contributions treat the demand function faced by the firms as linear, Kamien at al. (1992) extend the analysis to a broader class and demonstrate that the main results obtained prevail. In particular, they concern themselves with demand functions that are decreasing and differentiable for strictly positive prices, have a non-decreasing price elasticity, and are furthermore such that the total revenue function is strictly concave in the quantity produced. On the other side of the market, there is a patentee licensing his innovation to the industry by either auctioning a fixed number of licenses, announcing a fixed fee or royalty rate per unit of output produced under the new technology or a combination of the latter. Process innovations, i.e. technological advances reducing the marginal cost of production, are perceived as being the main type of innovation studied, however, as mentioned by Kamien (1992), the game theoretic framework described below is equally suitable to investigate the licensing of product innovations. The inventor himself may either engage in the competition play by being an incumbent or behave as an outsider to the industry unable to make a capacity or price commitment.

Coming back to the interaction between potential licensees and patentee the timing of the game is the following. On the first stage, the patentee announces the conditions under which a license can be obtained; that is the fixed fee, royalty rate or number of licenses to be auctioned. Firms then decide independently and simultaneously on how much to bid or how many licenses to purchase. Those decisions divide the firms in two subsets; licensees and non-licensees. Finally, on the third stage of the game, firms, belonging to either group, engage in profit maximisation by choosing prices (Bertrand Competition) or quantities (Cournot or Stackelberg Competition) depending on the nature of competition. It is assumed throughout the game that all relevant information are shared by the firms, i.e. are common knowledge, resale of licenses, asymmetries as well as uncertainty are ruled out and that the game is played once. However, as Kamien/Tauman (1983) critically mention, those aspects are non-trivial and most likely to affect the nature and outcome of the game.
Commonly, the notion of a subgame perfect Nash Equilibrium is employed as a solution concept. This brings with it that incredible threats and irrational behaviour on the equilibrium path are ruled out as the concept demands rationality, i.e. optimising behaviour, not only at the beginning of the game but also in every subgame. In the present context this implies that on the third stage, prices, quantities as well as profits of licensees and non licensees are determined. It is worth emphasising that the former maximise revenue net the cost of obtaining a license, where the specific form of the optimisation problem depends on the licensing mechanism announced. Comparing the profits, which can be realised with and without the new technology, the willingness to pay or bid for a license and therefore the demand for the latter are determined. Taking this into account the patentee then concludes on how many licenses to auction or at which price to offer them in order to maximise total licensing payoff. A graphical overview of the single stages of the licensing game may be found in section A.2 of the appendix.
So far, the implicit assumption has been made that the patentee is an outsider to the industry, for instance a research laboratory, unable to produce on its own. However, being equipped with production facilities the inventor might decide to engage in the competition play among the firms. In this case, his objective is not only to maximise licensing revenue, but rather total surplus including production profits.

In the following pages, the different modes of licensing together with their implication for the outcome of the game under either quantity or price competition are described in detail. The results for the case of a patentee being an industry outsider are presented, followed by recent contributions challenging the standard results.

## 2.1 Cournot Competition

### 2.1.1 The Industry Outsider Case

**Licensing via Auctions** At the beginning of the game, a fixed number of licenses is offered via a sealed-bid English auction. This implies that the highest bidders receive a license and pay an amount equal to their bid. Naturally, the maximal number of licenses potentially being offered coincides with the number of firms in the industry. How many licenses to auction, as well as the question of how to handle ties lies in the distinction of the inventor. Next, firms, depending on how many licenses the patentee

[1] See Kamien (1992)

chooses to auction, decide about their bidding behaviour. As mentioned above, the maximal amount a firm is willing to bid depends on the comparison of licensee and non-licensee profits, while the number of licenses is taken as given. Bidding more than this difference, firms can improve their revenue situation by not obtaining a license at all, while bidding a sightly lower amount will result in a loss of the license, everything else being equal. On the last stage, competition between licensees and non-licensees takes place, whereby the optimal quantities depend on the number of licenses auctioned and the affiliation to either subgroup (licensee or non-licensee).

For the analysis two subcases, depending on the extent of cost reduction triggered by the innovation, need to be considered separately. In this context, the distinction between a drastic and a non-drastic innovation is made.
For a drastic innovation, meaning that the licensee will set the post-innovation monopoly price below the pre-innovation competitive price[2], a single license is auctioned. This implies that the outside option of each firm is no production, i.e. zero profits. As a result, fierce bidding behaviour will ensure that the license is auctioned and all firms but the licensee are forced to drop out of the market. Hence, the market structure is altered towards a monopoly in which the licensee's entire profit is extracted by the patentee. For non-drastic, minor cost reducing innovations the result is reversed; the optimal strategy is shown to consist in licensing to the entire industry. As this fact is common knowledge to the firms, the inventor is required to set a minimal reservation price in order to prevent firms from bidding zero, knowing they will receive a license in either case. For innovations offering a slightly higher cost reduction the industry is split in the before mentioned subgroups. One part of the firms continues producing under the old technology, while the other, having obtained a license, is able to integrate the innovation in its production process. For cost reductions exceeding a certain threshold or industry size being sufficiently large the oligopoly reduces to the number of firms having obtained a license. It has to be emphasised that this number is such that the equilibrium price equals the cost associated with the inferior production technology. Hence, aggregate production corresponds to its complement under perfect competition. As price and pre-innovation cost are equivalent, it is intuitive that in this context the licensees' per unit profit coincides with the size of the cost reduction. However, as all other players are driven out of the market the firms' outside opportunity equals zero and the patentee is therefore able to appropriate the whole surplus.[3]

Compared to the pre-innovation outcome, the industry is now characterized by lower aggregate prices and higher aggregate quantities. What is more, in each case considered above, the licensees' payoffs are lower in the new equilibrium. As indicated previously, the surplus extractable by the patentee is negatively linked to the amount of licenses auctioned and outsider innovators are therefore "[...] *most likely to direct their efforts to providing significant inventions for less competitive industries*".[4]

In this context the question might arise why a firm chooses to purchase, or more precisely to bid a positive, non-zero amount for a license knowing that its post-innovation profits will be lower. Following Kamien (1992) this can be rationalised by the fact that firms are imposed to be unable to collude credibly. Thus, due to the bidding behaviour previously described, a fixed number of firms will be licensed and those not being among the set of licensees might be forced to drop out of the market.

**Licensing via Fixed Fees** Compared to the case of a license auction, a first difference arises due to the fact that in the current setting the patentee cannot target the number of licensees directly, but only indirectly by setting a fixed fee at which a license can be obtained. Kamien et al. (1992) show that in their general setup multiple equilibria, implying more than one level of licenses sold, can arise as a consequence.[5] Nevertheless, those can be ruled out by restricting the analysis to one of the following cases: a linear demand function, a willingness to pay for a license that is decreasing in the number of licenses sold or by allowing for discriminatory fees. Given the size of the industry, the inventor determines the optimal fee by taking the interaction between fee and licensees into account. More precisely, the amount to pay for a license is set such that no buyer has an incentive to deviate to not buying and vice versa for a non-buyer.[6] As observed by Kamien (1992), in determining a firm's willingness to pay the main difference to the previous case arises. Unlike in the auction game where the (fixed) number

[2]This definition goes back to Arrow (1962) and implies that $p_m = \frac{a+c-\epsilon}{2} < c \leftrightarrow \epsilon > a-c$ with $p_m$ denoting the monopoly price, $c$ marginal costs and $\epsilon$ the magnitude of the cost reduction.
[3]This figure represents the upper bound common to all pure licensing policies presented in this paper for the industry outsider case and non-drastic innovations.
[4]Kamien/Tauman (2002), p.10
[5]Specifically, due to the non-linearity of a firm's willingness to pay as a function of total licenses a level of a fixed fee implies several level of licenses sold.
[6]See Kamien/Tauman (1986)

of licenses sold cannot be altered by a firm bidding zero[7], the number of licensees can be reduced by a firm not purchasing the license in the present context. Therefore, on the second stage, firms decide whether or not to purchase a license based on a comparison of the profit obtainable with and without the new production technology, taking into account that in the latter case the set of licensees is reduced by one. Consequently, the opportunity cost of not belonging to the set of licensees in a license auction game exceeds the one occurring under a fixed fee scheme. From this it can be concluded that in the eyes of the patentee the optimal fee has to be such that for a licensee the opportunity cost of purchasing the license (oligopoly profit obtainable with the old technology, given that there is one licensee less) together with the fixed fee does not exceed the profit under the new technology. Conversely, for a non-licensee the opportunity cost of not purchasing the license (oligopoly profit obtainable with the new technology) together with the fixed fee must not be smaller than the profit obtainable as a licensee, given that there is one licensee more.[8] As before, the last stage is characterised by a competition play *à la Cournot*.

In the case of a drastic innovation it is shown to be optimal for the patentee to set the fixed fee such that he licenses to a single firm, hereby monopolising the industry. However, unlike in an auction game, the inventor is unable to extract the entire monopoly profit. Why does this difference emerge? Should a single license be offered in a license auction, the existence of a licensee is guaranteed. This is due to the outside option of zero profit as any firm not obtaining a license is driven out of the market. For a fixed fee licensing mechanism, however, a firm not purchasing a license can enter the oligopoly in which the whole industry employs the pre-innovation production technology.[9] Thus, as the number of licensees is not a choice variable of the inventor, the surplus extractable in the case of a drastic innovation is lower than in a license auction game. Intuitively, this difference vanishes as the size of the industry grows infinitely large and the outside option of a firm under fixed fee licensing approaches the profit obtainable in a perfectly competitive industry.
For a non-drastic innovation Kamien/Tauman (1986) demonstrate that the number of licensees is non-increasing in the magnitude of the innovation. This brings with it that for a cost reduction or the industry being sufficiently small in size all firms will obtain a license. For innovations sufficiently large in magnitude a small number of firms is licensed such that the Cournot equilibrium price coincides with the marginal cost of production when employing the pre-innovation technology. Firms not having obtained a license are forced out of the market. Values lying between the two extremes imply an industry characterised by a mixed technology in which both, licensees and non-licensees, produce positive quantities.

For any (non-zero) cost reduction a familiar conclusion concerning the market outcome is reached; quantities produced increase, while prices and profits fall. An exception arises for the case of a single licensee, who, in the context of a drastic innovation, is no worse off in terms of the profits obtained. This is due to the fact that the patentee extracts exactly the difference in profits triggered by the cost reduction. In general, licensing profits realisable under fixed fee licensing do not exceed their analogue in the case of a license auction. Equality is observed when the whole industry obtains a license, while a minimum reservation price ensures strictly positive bids. With the size of the industry growing infinitely large, both quantities, meaning licensing profits, are shown to approach one another. Hence, under the current licensing mechanism, the inventor has the highest incentive to innovate for a purely competitive industry. However, as demonstrated by Kamien/Tauman (1986), the most profitable industry size depends on the magnitude of the cost reduction and may coincide with neither extreme. What is more, under fixed fee licensing, aggregate prices as well as the number of licensees itself are no smaller than their analogue under a license auction.

**Licensing via Royalties** Following Kamien (1992), the highly uncertain nature of demand may serve as a Rationale behind the widespread use of royalties as a licensing mechanism. In this context, royalties, or uniform fees per unit of output produced under the superior technology[10], provide an arbitrage mechanism for both, licensee and patentee, by directly linking payment and output. Before describing each single stage of the licensing game itself, it has to be pointed out that the results are based on the implicit assumption that output is easily verifiable. However, the conclusions reached might change if monitoring costs or moral hazard considerations are taken into account.

On the first stage, the inventor determines the optimal royalty rate by maximising licensing income.

[7]Unless the inventor has to set a reservation price as the result of licensing to the whole industry.
[8]See Kamien/Tauman (1986)
[9]This result heavily depends on the assumption that the licensing contract cannot be re-offered to another firm.
[10]San Martín/Saracho (2010) show that in the case of a homogeneous good duopoly with the patentee being either in- or outsider to the industry, ad valorem royalties are preferred to per unit royalties in terms of licensing revenue, while the opposite might hold true for the oligopolistic industry.

As licensing revenue is positively linked with, next to the royalty rate itself, the units produced under the pre-innovation technology, it is quite intuitive that it lies in the interest of the patentee to increase the number of licensed firms. Consequently, for any non-drastic innovation, equalising royalty and magnitude of the innovation provides an optimal or revenue maximising strategy. To see this, it should be noticed that for any rate exceeding the cost reduction, no firm is willing to obtain a license, whereas for royalties falling below this threshold the profit of the patentee declines, while leaving the number of licensees unaltered. In such a subgame perfect Nash Equilibrium the number of licensees coincides with the number of firms in the industry as in any other instance (meaning a situation in which no firms obtains a license, due to the symmetry of the setting) a marginal reduction of the rate assures equivalence, while simultaneously making the patentee better off. Similarly, in the context of a drastic innovation, equalising per unit rate and monopoly price being set by the single licensee when employing the new production technology proves to be optimal. On the next stage, firms, under the common assumptions, decide whether or not to accept the offer of the inventor. Finally, prices and quantities, as well as profits are being determined as the outcome of a Cournot competition game.

For a non-drastic cost reduction, regardless its magnitude, following the previously described strategy implies that both groups, licensed and unlicensed firms, face equivalent marginal cost of production. Thus, individual and aggregate output, as well as prices remain unaltered by the introduction of the new technology.
In the case of a drastic innovation, however, the amount produced increases, resulting in a fall of prices; the (monopoly) profit of the sole licensee is fully extracted by the patentee. Hence, unless revenues are already zero prior to the introduction of the new technology, licensee and non-licensee are worse off compared to the pre-innovation situation.

From the perspective of the patentee, both modes of licensing described in the previous sections are preferred to a licensing via royalties in terms of revenue. An exception occurs for drastic innovations or the size of the industry growing infinitely large. In those cases one respectively observes that profits under licensing via auctions or royalties exceed those attainable under fixed fee licensing or that licensing revenues coincide over all three policies. As in the present framework profits increase with industry size, the inventor has the highest incentive to invest in the research and development of an invention ultimately being licensed to a perfectly competitive industry. What is more, market prices are shown to exceed the ones associated with an auction or fixed fee based compensation scheme. This is due to the particular character of royalties with respect to the optimisation problem. In contrast to per unit rates, both, the fixed fee as well as the auction bid, are a static part in the maximisation problem of the licensee and thus do not restrict the optimal quantities produced. Royalties, however, directly affect marginal costs and are optimally set to exactly outweigh the efficiency advantage associated with the superior production technology. Hence, while the efficiency advantage embodied in a process innovation commonly induces firms to increase equilibrium production, this effect is absent in the present context.

**Licensing via Two-Part Tariffs** The licensing policy predominantly observed in practice belongs to the class of two-part tariffs; a concept encompassing any combination of fee, auction and royalty licensing.[11] More precisely, depending on how the upfront fee is determined, this policy combines royalties with either auction or fixed fee mechanism.

On the first stage of the by now familiar three stage game, the inventor announces the licensing policy, meaning the per unit royalty rate together with either fixed fee or number of licenses to be auctioned. From the discussion above it is intuitive that a license auction weakly dominates its fixed fee counterpart in terms of the potential licensees' willingness to pay. Hence, at this stage, either of the following two policies is announced: the number of licenses together with the royalty rate in case the number of licenses auctioned is strictly less than the number of firms in the industry, or the number of licenses together with the per unit rate and a minimum bid for the number of licenses coinciding with the number of firms in the industry.[12] At the second stage, firms independently and simultaneously decide whether or not to accept the contract. Finally, quantity competition between the firms takes place. What is novel to this licensing mechanism is that in addition, depending on the individual production, royalty payments occur for the set of licensees.

[11]See Sen/Tauman (2007) for an overview of empirical evidence.
[12]In this section the terms fee and bid are used interchangeably as the upfront fee either coincides with the reservation price of the patentee or the highest bid(s). That is, the two terms are not necessarily associated with the mechanisms observed in the sections "Licensing via Auctions/Fixed Fees".

For drastic cost reductions a single firm is licensed exclusively.[13] In this context, the fee coincides with the monopoly profit attainable under the superior production technology, owing to the firm's zero outside option (similar to the license auction environment, the existence of a licensee is guaranteed, thus the reasoning associated with the fixed fee setting does not apply here). Consequently, each firm is worse off after the introduction of the innovation, unless the industry is already monopolised prior to it.
Restricting the analysis to the set of non-negative royalties[14], all firms except one are licensed for non-drastic, significant cost reductions. The non-licensee is driven out of the market as the new equilibrium price coincides with the marginal cost associated to the inferior production technology. For magnitudes of the cost reduction smaller than the mentioned threshold, at least as many firms as in the previous case are licensed. In this instance, the post-innovation Cournot price exceeds marginal costs of production. In both cases, the revenue of the licensor is bounded below by the total cost reduction for the pre-innovation output.[15] This result reflects the motivation underlying two-part tariffs; being able to employ two, instead of a single instrument, positive revenues potentially remaining with the licensee under a pure licensing contract can be extracted. As a natural consequence, the patentee's licensing profits cannot fall below their previous level.
For cost reductions sufficiently large, the optimal policy involves positive royalties. In reasonably competitive industries and for minor innovations the optimal per unit rate is zero; pure royalty contracts are never observed in the given setting. This point seems worth further elaboration. First, it has to be noted that for a rate strictly below the magnitude of cost reduction a difference in efficiency between the set of licensees and non-licensees arises, which presents itself in form of higher profits of the former group. As this gap can be extracted by the patentee in form of a positive fee, setting the fixed fee part equal to zero cannot be optimal. Second, for equivalence of the two quantities, i.e. a pure royalty contract, the results of the previous subsection apply; the patentee's revenues are lower than the shared upper bound, unless the size of the industry grows infinitely large. Here, no further characterisation of the royalty rate can be given. The reader may refer to Sen/Tauman (2007), who, providing a numerical example (p.183, table A.5) explicitly derive the equilibrium quantities for specific values of the industry size.
In general, firm income is lower as net revenue coincides with the outside opportunity, which, due to the presence of a guaranteed group of licensees, falls short of its analogue in the pre-innovation situation.

The result reflects the relative effects respectively associated with the single policies involved. Under pure royalty licensing, setting the per unit rate equal to the magnitude of the cost reduction together with licensing to the whole industry is optimal from the perspective of the patentee. Under fixed fee licensing the industry is reduced to the narrow set of licensees for significant innovations. In combination, a positive royalty rate serves to expand the set of licensees, while restricting it to not exceed the cost reduction, a positive fee is potentially extracted.

Depending on the magnitude of the technological advance, the industry size that provides the highest incentives to innovate takes the form of a u-shaped step function (Sen/Tauman (2007)); for minor cost reductions, or those close to being drastic, licensing revenues are maximised for industries approaching an environment of perfect competition. This is in line with the results obtained for the pure policies involved. As stated previously, insignificant innovations are being licensed for a positive fee and zero per unit rate, while those of larger magnitude involve positive royalties. What is more, on the basis of preceding conclusions, the inventor's licensing revenue is maximised for industry size growing infinitely large, for either policy involved.

**Comparing the Different Policies** The comparison of the various pure licensing mechanisms reveals an auction based policy as licensing revenue maximising, while the reverse holds true for a royalty contract. Prices associated with a royalty mechanism exceed, in this order, those under fixed fee and auction, while the opposite is observed for quantities. Concerning the incentive to innovate heterogeneous results are reached. Employing the superior licensing policy, incentives are maximised for the monopolised industry. Conversely, for the remaining two schemes, gains from licensing increase in industry size respectively due to a diminishing outside opportunity or a positive correlation of royalty and licensing revenue. As a corollary, the innovation experiences the most widespread diffusion for a per unit based policy.
Despite their intuition, the theoretical results obtained are contrary to empirical evidence that unanimously supports the predominance of royalty based schemes.[16] This observation presents the starting

[13]See Sen/Stamatopoulos (2009) on the multiplicity of optimal licensing policies.
[14]See Liao/Sen (2005) for implications of negative royalties (subsidies) for a Cournot duopoly.
[15]The reader might recall that this figure represents the upper bound of licensing revenues under either pure licensing mechanism previously discussed for non-drastic innovations.
[16]See e.g. Rostoker (1983) or Bousquet et al. (1998)

point for a by now vast amount of research that aims at rationalising the popularity of royalty licensing mechanisms. This is achieved by either relaxing assumptions of the classical framework or introducing new considerations into it. The reminder of this paper attempts to give a, by no means exhaustive, overview of those approaches, ranging from purely technical aspects over different modes of competition to the introduction of product differentiation or asymmetries. In particular, focus is put on the question of how the market structure affects the optimality of the licensing mechanisms.

### 2.1.2 The Industry Incumbent Case and Other Extensions

A first challenge to the predominance of auction over fixed fee and royalty licensing in terms of the profit of the outside innovator stems from the fact that the number of licenses offered can only take integer values. However, in the analysis so far, this figure has been treated as a continuous variable. With regard to non-drastic innovations it first has to be recalled that there is a shared upper bound to licensing revenues for licensing via auction or royalties, namely the total cost reduction for the pre-innovation competitive output.[17] As industry size grows infinitely large, this bound is reached asymptotically under royalty licensing. Alternatively, given industry size exceeds a certain, previously mentioned threshold, this figure is attained by auctioning off a number of licenses such that the Cournot equilibrium price of the induced oligopoly coincides with the pre-innovation price. However, this number (more precisely $\frac{a-c}{\epsilon}$) is an integer "*for all but countably many magnitudes of the innovation*".[18] That is, imposing the integer restriction for *countably many magnitudes* of the cost reduction, royalty licensing dominates licensing via auctions in terms of licensing profits and vice versa.
In this context I would like to draw attention to an interesting result obtained by Giebe/Wolfstetter (2008). For the outside innovator, licensing to an oligopolistic industry shaped by competition *à la Cournot*, a combination of auction and per unit rate is superior to all of the previously elaborated policies, even under consideration of the integer constraint. The observed predominance rests on several impositions particular to the design of the mechanism. Most importantly, royalty contracts are offered via a common auction, while those agents, not having obtained a license in the first instance are granted per unit based contracts.

Also certain characteristics related to firm size may possess explanatory character concerning the widespread use of royalties in licensing contracts. However, considerations of this kind are absent in the literature. In this context it is worth quoting Beggs (1992), p.172, who remarks that "*it is not clear from empirical studies whether firm size does affect the licensing of contracts*".[19] Hence, the discussion of the following paragraphs may also provide some closure to this gap from the theoretical side. Here, focus lies on three characteristics, commonly associated with larger firm size. Namely, a convex cost structure, reflecting the presence of diseconomies of scale, a separation of ownership and control, as well as the possibility to conduct research and development in-house.
Although the driving forces underlying diseconomies of scale are subject to debate, the idea of larger companies being, from a certain point on, characterised by convex cost structures finds widespread acceptance.[20] In the framework, an external patentee licenses his cost reducing process innovation to an oligopolistic industry. What is novel to the setting are two assumptions, namely convex costs and a zero outside opportunity of the potential licensees[21], which bring several non-trivial implications with them. First, it can be deduced that auction and fixed fee licensing are equivalent in terms of licensing profits. Moreover, as marginal costs are increasing in output, the negative effect of the diseconomies of scale is reduced for industry size growing large. To fully grasp the intuition behind this result, consider the case of a royalty based licensing scheme. In the previous section it is shown that under this policy, individual production levels are distorted downwards compared to the case of a fixed fee or auction based policy. What is more, licensing to the whole industry is optimal in terms of licensing profits. In the current context this implies that total production costs are reduced as firm-level production is lower *per se* and, additionally, aggregate industry output is allocated over the producing agents. As a consequence, licensing via royalties may generate higher licensing revenues, provided industry size is sufficiently large, and the increase in profits outweighs the output distortion on the level of the firm.
Saracho (2002) proposes another way to rationalise the predominance of royalty based licensing policies

[17] In line with Sen (2005) it is sufficient to concentrate on auction and royalty based schemes as licensing via auctions dominates fixed fee licensing in terms of the patentee's revenues. That is, to implement the predominance of a royalty based licensing scheme, its superiority to the auction policy has to be demonstrated.
[18] Sen (2005), p.146
[19] A recent study by Zuniga/Guellec (2009) reveals the relationship between firm size and likelihood of technology transfer as u-shaped; small and large companies are characterised by a high propensity to license.
[20] See Canbläck et al. (2006) for a review of the literature.
[21] This corresponds to the case of a drastic innovation. Additional intuition may be found in Mukherjee (2010).

that is observed in practice.[22] In the familiar game-theoretic framework two observations concerning the leadership structure of modern corporations are explicitly taken into account; separation of ownership and control, as well as incentive based compensation schemes. This adds a new dimension to the decision problem of the firm owner. It now not only concerns the question of whether or not to obtain a license, but also the form of the optimal incentive scheme. In the framework chosen by the author, such an incentive scheme is assumed to depend on profits as well as output. This implies a change of objective to compensation, rather than profit maximisation as the choice of optimal quantities lies in the distinction of a manager. As a result, output is larger than in the absence of strategic delegation for sufficiently concentrated industries. Consequently, for innovations within a particular interval, which itself depends on the size of the industry, and a small number of competitors, licensing via royalties is optimal. As the size of the industry grows, providing managers with incentives to increase output becomes costly; "*firms cannot afford to do anything other than be profit maximizers*"[23]. In this instance, fixed fee licensing might dominate a royalty based scheme.
As it has been stated earlier, for a non-drastic innovation of sufficient size the patentee maximises his payoff by auctioning a number of licenses such that the previously mentioned upper bound is attained. For the innovator being an industry incumbent, however, this result is reversed in favour of royalty licensing. Wang (1998) rationalises this conclusion arguing that, as setting a royalty rate equal to the magnitude of the cost reduction still proves to be optimal, the patentee benefits from a cost advantage, while the licensees' cost positions remain unchanged. Under fixed fee or auction licensing, however, both, inventor and licensees, compete under equivalent cost structures. So far only pure licensing mechanisms are considered. However, allowing for negative fixed fees and royalty rates exceeding the magnitude of cost reduction, the monopoly outcome can be implemented via a two-part tariff. Nevertheless, taking antitrust considerations into account, the two part scheme reduces to a pure royalty contract.[24] Closely related to this matter, Sen (2002) proposes a royalty based licensing mechanism in which the optimal rate depends on the number of licensees. It is shown that for industries composed of more than three firms, the incumbent inventor is able to obtain the monopoly profit associated to the superior technology for any non-drastic innovation, while respecting the anti-trust related constraints on fee and royalty rate.

It has to be remarked critically that the results obtained for the patentee being an industry incumbent heavily rely on the hypothesis that all firms in the industry are potentially able to obtain a license. Relaxing this assumption, a pure fixed fee contract might be chosen within the class of two-part tariffs, given the number of potential licensees relative to industry size is sufficiently small. Intuitively, licensing an industry rival has two effects on the patentee's profits. On the one hand, revenue stemming from licensing itself is created. On the other side, production profits decrease as a consequence of the rival being able to produce with the superior technology. In the standard framework the last effect vanishes for a per unit rate equal to the magnitude of the cost reduction. However, with one part of the industry unable to obtain a license it turns out to be profitable for the patentee to have more efficient licensees as this reduces the market share going to those firms producing under the old production technology.[25] Thus, a pure fixed fee contract is optimal from the perspective of the inventor.
The mechanism described in the previous paragraph also rationalises the dominance of fixed fee over royalty licensing in an alternative framework. Introducing a second patentee, while ruling out competition for licenses among the firms in the industry, Fosfuri and Roca (2004) illustrate that the benefit of having a more efficient licensee exceeds the loss due to increased competition. Interestingly, in this scenario profits from fixed fee licensing are smaller than those potentially obtainable under a royalty based policy. Nevertheless, as firms cannot credibly commit to a royalty mechanism, fixed fee licensing dominates.

In closing this subsection it feels natural to anticipate a topic that finds further elaboration in a subsequent chapter of this work.[26] Namely, how the introduction of asymmetries has the potential to alter the conclusions reached so far; here, for instance, in favour of a fixed fee contract. The subject of investigation is a Cournot duopoly, shaped by cost asymmetries in the sense that one firm takes on the role of the efficiency leader, i.e. benefits from a smaller marginal cost of production. In this setting a non producing patentee aims at licensing a technology that reduces marginal cost, however, not below the level associated with the more efficient incumbent. As a consequence, a strategic incentive arises for this agent. The exclusive acquisition of the technology for the sole purpose of maintaining supremacy

[22] The model demonstrates the superiority of royalty licensing over a fixed fee based policy in a number of circumstances. However, as the author remarks, both mechanisms are dominated by a license auction.
[23] Fershtman/Judd (1987) in Saracho (2002) p.239
[24] See e.g. Katz/Shapiro (1985)
[25] Specifically it is assumed that the magnitude of the innovation given the cost structure is sufficiently small such that firms not having obtained a license do not drop out of the market.
[26] See 4. Asymmetries, p.17-19.

in terms of efficiency becomes desirable. Exploiting the degree of competition optimally, the patentee auctions off a single license. As a direct result of the asymmetric setting, equilibrium bids differ and the firm characterised by the most pronounced willingness to pay marginally outbids its rival. Employing a fixed fee based scheme a clear cut conclusion is reached. Based on the emphasised difference between auction and fee mechanism only the less efficient firm is characterised by an incentive to obtain a license. Hence, licensing income coincides with the least efficient firm's willingness to pay. In comparing both policies with view on licensing revenue, two subcases emerge. Firstly, if the efficiency leader's willingness to pay exceeds the one of its industry rival, both schemes coincide. In the reverse situation, however, the previously claimed result follows. To see this note that in this instance licensing income stemming from an auction mechanism equals the willingness to pay associated with the more efficient firm. Conversely, under fixed fee licensing the patentee's revenue amounts to the willingness to pay of the incumbent characterised by higher marginal cost. By assumption, the latter amount exceeds the former.

### 2.2 Stackelberg Competition

By capturing some sort of asymmetry between the agents, also the introduction of a leadership structure potentially alters the conclusions reached so far. In the current framework, the market environment is one of Stackelberg competition in which a dominant firm, the leader, and its follower compete by choosing quantities. Relaxing the imposition of simultaneous moves at the industry competition stage, the leader is characterised by a first mover advantage, meaning that he maximises his objective function anticipating the best response of the follower. This, among other things, shows itself in a heterogeneity of individual production levels, beneficial for the agent moving first.
Although the main questions continue to concern incentives to innovate as well as performance of different licensing mechanisms, a discrepancy to the former environment arises; the identity of the potential licensee, i.e. whether the firm is leader or follower, becomes an important consideration to the patentee.[27]

#### 2.2.1 The Industry Outsider Case

The results presented in the following paragraph predominantly follow Kabiraj (2004), who assumes the patentee to be an outsider to a duopoly industry, characterised by Stackelberg competition. The fundamental structure of the licensing game is unaltered. On its first stage, the inventor decides which firms to license to and subsequently announces the conditions particular to the licensing mechanism. Thereafter, leader and follower decide whether or not to accept the contract. On the last stage, sequential competition play takes place.

**Licensing via Auctions** In the license auction game a single license is given to the leader as long as the innovation is non-drastic; for a drastic cost reduction the auction results in a tie. To fully grasp this result it has to be recalled that the maximal willingness to pay for a license is based on the comparison of the profit attainable under the new production technology, taking into account that the rival did not receive a license, and the one realised in the reverse situation. For a non-drastic innovation this difference turns out to be larger for the leader, whereas for a drastic innovation equivalence is observed. As a result, in any instance, the dominant firm will bid at least as high as its follower. In comparison to the previous section the crucial point is that under Cournot competition the willingness to bid is not indexed on the single firm, due to the absence of sequential moves and the related equivalence of bids over firms. However, as the leader is able to commit to quantities in the current framework, he is potentially able to outbid the less dominant firm.

**Licensing via Fixed Fees** Depending on the nature of the innovation, the inventor licenses exclusively to either agent under fixed fee licensing. That is, in case of a non-drastic minor innovation, the leader takes on the role of the sole licensee, while the reverse holds true for innovations of larger magnitude, including the case of drastic cost reductions. How can this result be rationalised? Being able to make a capacity commitment, the leader realises a profit that exceed the one of the follower for a non-drastic innovation, while for a drastic cost reduction both quantities coincide. However, this first mover advantage also presents itself in form of a larger outside opportunity of the leader. As the highest amount the patentee can appropriate via a fixed fee is depicted by the discrepancy between outside opportunity and profit attainable when employing the superior production technology, the desired result follows. Licensing to both firms never proves optimal as the competition play between the firms reduces the increase in surplus that is due to the efficiency effect.[28]

[27] See Kabiraj (2004)
[28] See Kabiraj (2004)

**Licensing via Royalties** Should the licensing mechanism take on the form of a royalty based policy, exclusive licensing to the leader dominates licensing the follower for any magnitude of cost reduction. Nevertheless, for non-drastic innovations, both firms obtaining a license is revenue maximising. Another exception occurs in the case of a drastic innovation. In this instance, exclusive technology transfer to the leader is superior if and only if the marginal cost of production prior to the innovation is sufficiently large.[29] The reason underlying this observation is quite intuitive. Royalties incur per unit of output produced under the innovative technology. Therefore, total licensing income increases in the quantity produced. Moreover, owing to the leadership structure, output of the dominant firm exceeds the one realised by the follower for any cost of production. In the same vein, licensing to both agents for a non-drastic innovation is rationalised. Setting the maximal royalty rate, the relative cost position and hence prices as well as production of licensee and non-licensee remain unaltered. Consequently, licensing solely to a subset of firms constitutes a loss in licensing revenue.

**Comparing the Different Policies** A comparison across the single licensing mechanisms reveals that for minor innovations the licensing revenue of the patentee attains its maximum for a royalty based licensing scheme in which each of the competing firms obtains a license. For those cost reductions exceeding a certain threshold, the order is reversed in favour of the license auction. In general, an auction mechanism remains superior to a fixed fee based scheme.[30] As a corollary, it can be conjectured that the industry size that maximises incentives to innovate is decreasing in the cost reduction. All in all, compared to Cournot competition, a diverging conclusion is reached. In an environment of static quantity competition, a license auction is preferred to its per unit based analogue for a minor cost reduction[31], while the reverse is observed in the present context. Nevertheless, both compensation schemes imply a full diffusion of the technology. Kabiraj (2004) rationalises this difference by the fact that under Stackelberg competition aggregate industry output exceeds the one of Cournot competition, a fact in favour of royalty based licensing schemes.

### 2.2.2 The Industry Incumbent Case and Other Extensions

The superiority of the royalty based licensing mechanism is even strengthened if the leader is assumed to be in possession of the cost reducing innovation. The results presented stem from a framework in which technology transfer from the industry incumbent to a single follower is investigated. However, extending the analysis to a leader and $k \geq 1$ symmetric followers, Filippini (2005) demonstrates that the main results obtained prevail.

Constituting the basis of the remainder of the paper, the industry incumbent case and the dynamics proper to it are already described in detail at this point. In this context, a remark has to be made; as the analysis focuses on a duopoly framework, the incumbent inventor has to set a minimum bid when employing a license auction. This brings with it, that the distinction between fixed fee and auction licensing mechanism vanishes, as, quite intuitively, the reservation price coincides with the potential licensee's willingness to pay under a fee-based scheme. Hence, only the latter is considered in the following paragraphs.

**Licensing via Fixed Fees** In a fixed fee licensing game, technology transfer solely occurs, given the magnitude of cost reduction is sufficiently small; in any other instance, the leader takes on the role of the industry's monopolist. Licensing to an industry opponent affects the innovator in a twofold way. On the one side, there is the imminent loss in market profits, reflecting the presence of a more efficient rival. Nevertheless, licensing via a fixed fee also presents a source of licensing revenue not to be underestimated, particularly for significant cost reductions. However, in the given setting, the former effect outweighs the latter for drastic innovations and no technology transfer takes place. Conversely, in the case of an incremental innovation, the threat embodied in competing against a more efficient industry rival is minor. Hence, by transferring the advanced technology the patentee is able to reap licensing income, while the negative impact on market profits is negligible.

**Licensing via Royalties** In the class of royalty based contracts, licensing to the follower is shown to be revenue maximising for the patentee, irrespective the magnitude of cost reduction. For drastic

[29]This conclusion is reached by defining a threshold level of the cost reduction such that the innovator is indifferent between licensing both or only the dominant firm. Restricting this threshold to not exceed the marginal cost of production, the desired result follows. See Kabiraj (2004).

[30]As shown by Kabiraj (2004) fixed fee licensing to the leader can be a superior strategy restricting the analysis to the case of single licensing, while allowing the patentee to re-offer the license in case his first offer is rejected.

[31]In fact both thresholds, i.e. for Cournot and Stackelberg competition, coincide for an industry composed of two firms ($n = 2$). According to Kamien (1992), p.340, the whole industry is licensed for $\epsilon \leq \frac{2(a-c)}{3n-1}$ in a license auction, while Kabiraj (2004), p.198 observes the same phenomenon for a per unit based scheme provided $\epsilon < \frac{2(a-c)}{5}$.

innovations the leader optimally sets a royalty rate such that the output of the follower is zero; the industry is monopolised. Should the innovation instead be non-drastic, the optimal royalty rate exceeds the magnitude of the cost reduction. In this context, a difference with respect to other authors (e.g. Wang/Yang (2004)), who constrain this rate to be no larger than the magnitude of innovation, emerges. Nevertheless, introducing limits to contract enforceability[32], it is demonstrated that similar conclusions are being reached in the present, unconstrained framework. How should this positive gap between royalty rate and cost reduction be interpreted? For the licensee, paying a rate per unit of output that exceeds the benefit induced by the innovation is comparable to an increase in per unit production cost. Nevertheless, its output as well as profits remain unchanged. To entirely follow this result, it has to be noted that under this licensing policy, production of the leader turns out to be below the level realised with the pre-innovation technology, whereas the followers' output remains unaltered. As a consequence, aggregate output is lowered, while prices experience an increase, outweighing the rise in cost.
In this context, an interesting observation is made by Filippini (2002). Under royalty licensing, there exists an interval for the magnitude of the cost reduction, such that the profits of the patentee increase when committing to the old production technology. This implies that the inventor has an incentive to employ the inferior production technology, while licensing the innovation.

**Comparing the Policies** In contrast to the industry outsider case, the incumbent innovator maximises total income by employing a royalty based policy. Consequently, incentives to innovate are increasing in industry size. The distinction to the previously obtained results arises due to the formerly addressed trade-off faced by the patentee when making his licensing decision. This is tightly connected to the observation that in the current environment the inventors' objective is to maximise total profit, meaning licensing income as well as market revenue. While under fixed fee licensing, both, patentee and licensee, compete under equivalent marginal costs, the former realises an efficiency advantage when choosing a per unit based mechanism. Consequently, the threat of a more efficient industry rival is mitigated, without loosing a source of licensing profits.

Should instead the follower be in possession of the innovation, the dominant firm will obtain a license under either mode of licensing, provided the innovation is non-drastic. Owing to the fact that the follower is unable to make a capacity commitment, the revenue maximising licensing mechanism is attained by equalising royalty rate and cost reduction. This in turn implies lower licensing revenue in comparison to the previous case. Therefore, it can be concluded that a dominant firm is characterised by higher incentives to innovate. Furthermore, due to the superiority of royalty licensing, those incentives are positively correlated with the number of potential licensees.
In this context, the question of for which firm licensing is more likely to occur, might arise. Wang/Yang (2005) remark that this is the case for the follower, regardless of the licensing policy employed. This is perceived as rather intuitive. Due to the first mover advantage of the patentee, the willingness to pay for a license is higher for the dominant firm, by this giving relatively larger licensing incentives to the follower.

A remark on the stability of the leadership structure concludes this section. Allowing for efficiency differences between leader and follower, the implied leadership structure need not to be stable. That is, imposing that the less efficient firm takes on the role of the patentee and, in addition, the magnitude of the innovation exceeds the initial cost difference between the two players, so called leapfrogging might occur. In particular, under royalty licensing the prior less efficient follower assumes the role of the leader regardless of whether it chooses to license to its rival. Conversely, under fixed fee licensing, a change in leadership structure is solely observed for significant cost reductions, in which case no licensing occurs.

### 2.3 Bertrand Competition

As it is a well known result in the literature, price competition in an industry characterised by constant and identical costs yields zero profit to all firms (*Bertrand Paradox*). This outcome prevails under the introduction of a superior production technology, unless the patentee licenses his innovation to a single firm.
This is why on the first stage of the licensing game, the patentee either auctions a single license, sets a fee equal to the licensee's profit or decides on a royalty rate equal to the magnitude of cost reduction or the monopoly price depending on the nature of the innovation. Next, the licensee accepts or rejects the offer and competes with the other firms by setting prices.

[32]Meaning the potential licensee only fullfills the contract given production under the superior technology is optimal. In particular, $r \leq \epsilon$ is introduced as an additional constraint in the optimisation problem with $r$ denoting the royalty rate and $\epsilon$ the magnitude of cost reduction.

In the context of a non-drastic innovation, the single licensee will set a price equal to the marginal cost associated with the inferior technology and by doing so drive the other firms out of the market. For a drastic innovation, this agent will choose a price below the pre-innovation cost level and realise the monopoly profit. However, as the outside opportunity of the licensed firm under either mode of licensing is zero, the patentee can extract the entire profit. In the case of a drastic innovation this amount coincides with the monopoly profit and for a non-drastic innovation depends on the magnitude of the cost reduction as well as the level of output produced under the pre-innovation cost.

**Comparing the Different Policies** As it is implied by the analysis so far the three licensing policies are equivalent for the patentee when firms compete in prices. On the one hand, due to an outside option of zero profit under either mode of licensing, the distinction between auction and fixed fee based policies disappears. What is more, as output under Bertrand competition is commonly higher than under Cournot competition, royalty licensing becomes more attractive by this closing the gap to the prior dominant strategies.
Kamien et al. (1992) show that in their general setup, either mode of competition yields the patentee an equivalent payoff, provided the cost reduction is sufficiently large (zero outside option for the potential licensee) in the case of a non-drastic innovation. A comparison of the profits across the two concepts of competition reveals that firms can realise a higher revenue under price competition, given royalty licensing, while the reverse may hold true for licensing under a fixed fee.[33]

## 3 Product Differentiation

In the work presented so far, firms are assumed to be homogeneous with respect to the product market. By relaxing this assumption in the current chapter, a new dimension is added to the nature of competition that potentially affects the licensing game. More precisely, in the present environment firms produce differentiated products, while the degree of differentiation has a non-trivial effect on the optimality of the licensing mechanism. As the reader might anticipate, the degree of differentiation itself is independent of the licensing mechanism chosen, but not the reverse.
To provide insight in the dynamics proper to the case of product differentiation, the licensing behaviour of an industry incumbent under either Cournot or Bertrand competition is analysed in a preliminary step. Why does the focus lie on an patentee being an insider to the industry? On the one hand, the dynamics distinguishing competition in homogeneous products to the current framework are most pronounced in the industry incumbent setting. Additionally, the analysis complements the previous section in which emphasis is put on the industry outsider case. The remainder of the chapter is then composed of two subsections devoted respectively to sequential and spatial competition.

Throughout the chapter, the setting is the following. The industry is composed of two firms competing under either mode of competition. Unless mentioned otherwise, products are horizontally differentiated, meaning they are distinct from one another in the perception of the consumer and across those agents for a given price. Following the seminal work of Singh and Vives (1984), the inverse demand functions of the consumers are derived from the optimisation problem of a representative agent, maximising a quadratic utility function, by this implying linearity of the demand structure. Focusing exclusively on substitutability concerns, the parameter reflecting the degree of product differentiation ($d$) is restricted to non-negative values, i.e the open interval[34] from zero to one. This brings with it that demand is negatively linked with its own price and upward sloping in the price set by the industry rival, while the degree of differentiation determines the intensity of the latter effect. Note that larger values of $d$ imply higher substitutability and therefore a more pronounced reaction of own demand on price changes by the competitor.

### 3.1 Cournot Competition

The licensing game itself is essentially the same as in the previous chapter. On its first stage the patentee announces the licensing policy as well as the conditions particular to it. Due to the necessity of setting a minimum bid in the duopoly industry insider case, auction and fixed fee mechanism are equivalent and attention is restricted to a fixed fee compensation scheme. Next, the potential licensee, depending on its outside option, decides whether to accept the contract or not. Finally, quantity competition between patentee and firm takes place.

[33]See Kamien/Tauman (1986) for details.
[34]Some authors consider the closed interval, i.e. $d \in [0, 1]$, $d$ denoting the degree of differentiation. This will be indicated should different conclusion be reached for boundary cases. Note that $d = 1$ corresponds to the previously discussed case of homogeneous products.

**Licensing via Fixed Fees** Under a fixed fee based scheme the maximal licensing revenue the patentee is able to appropriate is depicted by the difference in profits of the industry rival, triggered by accepting the licensing contract. In determining the optimal fee, the inventor faces a trade-off. On the one side, everything else being equal, licensing the rival firm increases competition and thus lowers marginal profit. Nevertheless, it also represents a source of licensing income. It is obvious that licensing occurs in case the latter effect outweighs the former. For any non-drastic[35] innovation this holds true, except for the products being sufficiently similar and the cost reduction large in magnitude, including the case of drastic innovations. Transferring such technologies to a competitor entails tougher post licensing competition, which is even amplified as the degree of substitutability approaches one. This is in accordance with the conclusion reached in the case of non-differentiated products in which only incremental innovations are being licensed under a fixed fee based policy. Investigating the likelihood of technology transfer further, Mukhopadhyay et al. (1999) draw a similar picture. Introducing horizontal product differentiation together with a symmetric conjectural variation, the authors show that within the Cournot regime technology transfer is profitable for the patentee provided the degree of differentiation is significant, or, otherwise, the magnitude of cost reduction not too pronounced.

**Licensing via Royalties** For a royalty based compensation scheme, licensing is profitable from the perspective of the patentee for any combination of cost reduction and degree of product differentiation. This stands in stark contrast to the homogeneous good case within the industry incumbent framework in which drastic innovations are never licensed. Wang (2002), p.260 classifies this result as "*an extreme outcome that breaks down if the goods are imperfect substitutes*". With products loosing similarity in the perception of the consumer, competition softens and the patentee can reap licensing revenue from the *other market*, without experiencing a strong decrease in own production profits. Another particularity inherent to the framework is the value of the royalty rate itself. The reader might recall that this rate is respectively set equal to the magnitude of the cost reduction or the monopoly price for non-drastic or drastic innovations. Here, this holds only true asymptotically, for the degree of differentiation approaching either zero or one. In any other instance, equivalence of rate and cost reduction is solely observed for innovations of minor degree. Transferring technology advances exceeding a certain threshold, including the case of drastic innovations, the royalty rate optimally equals a quantity that is bounded from above by the monopoly price and coincides with it for the boundary cases of perfect or complete absence of differentiation.[36]

**Licensing via Two-Part Tariffs** In the class of two part tariffs, the dynamics behind the previously described pure licensing mechanisms are reflected in the optimal policy. That is, the larger the degree of product differentiation, the more significant the contribution of the fixed component on licensing revenue. In particular, for products close to being homogeneous, the royalty rate is set to equal the magnitude of the cost reduction, implying a fee of zero. To rationalise this result it has to be taken into account that for the products being close substitutes, competition between licensee and patentee is strong. Thus, the patentee theoretically prefers setting a royalty rate that exceeds the cost reduction, while simultaneously paying a subsidy to the firm in form of a negative fixed fee. Restricting the analysis to non-negative fees and royalties that are bounded by the magnitude of the innovation, the previous result follows. In contrast, as the goods grow increasingly distinct, the fixed component gains in importance, while the opposite holds true for the variable part, meaning the per unit rate. Consequently, at the other extreme, namely perfect differentiation, pure fixed fee licensing is superior in the eyes of the patentee.

**Comparing the Different Policies** In the classical framework it is argued that for an industry incumbent licensing revenues stemming from a royalty based scheme are at least as high as those attained under fixed fee licensing. A slightly distinct conclusion is reached in the current setting. Royalties are found to be superior to a fixed fee mechanism, except for a large degree of product differentiation together with either minor or drastic innovations. In general, a large degree of product differentiation implies soft competition following the transfer of a superior technology. Furthermore, setting a positive royalty rate increases the effective marginal production cost and therefore negatively affects the firm's post-innovation production. Consequently, taking the positive correlation of the patentee's licensing revenue with output and magnitude of the cost reduction into account, employing a fixed fee based scheme is beneficial

[35] For the interested reader it is mentioned that under product differentiation this threshold corresponds to $\frac{(2-d)(a-c)}{d}$, $d$ degree of product differentiation. It is obvious that the two quantities coincide in the limit case for $d$ approaching one.

[36] In Wang (2001) the royalty rate ($r$) is found to equal $r = \frac{8-3d^2+d^3}{8-3d^2}(\frac{a-c+\epsilon}{2}) = Bp_m$ for $\epsilon \geq \frac{8-4d^2+d^3}{8-2d^2-d^3}(a-c)$. It is easily shown that $\lim_{d \to 0,1} B = 1$. Moreover, own calculations reveal that the minimal value of B, and consequently r, is attained at $d = 0.712$ implying $B = 0.977$. What is more, the maximal value of $B$ for $d \in (0,1)$ is reached at 1.

for minor innovations. For drastic-innovations and highly differentiated products the potential licensee is characterised by a high willingness to pay. Setting an appropriate fixed fee, the patentee is able to extract this willingness to pay, without experiencing a significant decrease in market profits. Introducing two part tariffs, this form of licensing contract turns out to be superior for sufficiently differentiated products; in any other instance the result is reversed in favour of per unit royalties.

### 3.2 Bertrand Competition

Under product differentiation, price competition no longer implements the perfect competition outcome. In particular, even for equivalent cost structures, prices diverge from production costs allowing firms to realise positive market profits. While in the absence of substitutability considerations all licensing mechanisms were found to be equivalent in terms of licensing revenue, royalty licensing dominates the remaining policies in almost every instance of the given framework. As the conclusion reached for either fixed fee or royalty based licensing mechanism as well as the intuition driving these results are highly similar in both competitive environments, only a comparison of the two policies is elaborated. For further detail the reader may refer to Wang/Yang (1999).

**Comparing the Different Policies** A comparison across the single policies reveals royalty based licensing to be the revenue maximising policy for non-drastic innovations. An exception occurs for minor cost reductions together with a highly heterogeneous product market. In the case of a drastic innovation, however, a per unit rate is solely favoured for an intermediate degree of product differentiation; a strongly differentiated product market is reflected in the superiority of fixed fee licensing, while a large homogeneity goes hand in hand with a monopolised industry, i.e. the absence of licensing.
The reader might notice that, compared to Cournot competition, a qualitatively similar result is reached. Commonly, Bertrand competition is associated with a more competitive environment, while the Cournot framework is perceived as being closer to a monopolistic setting. Introducing product differentiation, lessens the competitive pressure under price competition and thus diminishes the gap between both concepts.[37] At this point, an interesting link with the before mentioned paper by Saracho (2002) can be made. Employing a conjectural variable approach, the author reaches a qualitatively equivalent result in a homogeneous product framework with an outside innovator; for firms competing *à la Cournot*, royalty dominates fixed fee licensing for sufficiently competitive industries and minor cost reductions. This indicates that the degree, rather than the nature of competition *per se*, represents a major force in determining the superiority of a licensing mechanism.

### 3.3 Stackelberg Competition and Further Remarks

I would like to complete the previous two subsections with some remarks. The first concerns the debate on ad valorem versus per unit royalties. While this issue was only briefly addressed within the classical framework, it is a point worth emphasising in the current context as the dynamics underlying this topic are more pronounced when differentiability and industry incumbent considerations are taken into account.[38] Although ad valorem royalties, or quotas on market profit obtained under the new production technology, seem to constitute a more feasible alternative with respect to moral hazard or observability issues, a conflict between theory and empirical evidence arises. For instance, citing a survey of French firms Bousquet et al. (1998) show that 96% of all royalty licensing contracts involve ad valorem royalties; a clear predominance that cannot be supported in neither of the here presented cases. The following discussion aims at providing some insight in that matter.
As it is a by now well known fact, licensing revenues are increasing in aggregate output for per unit royalties, while they are positively related to the price associated with the licensee's production under a value based scheme. Abstracting for a moment from other considerations, it can hence be conjectured that in a competitive environment in which the licensee is characterised by a high level of revenue an ad valorem policy is beneficial for the patentee and vice versa for a pronounced level of production. Furthermore, by reducing own production levels this connection works to the benefit of the inventor; his strategy results in an increase of market profits of the industry rival and thus, everything else being equal, higher licensing revenues. This effect is of particular importance for a high degree of substitutability on the product market as it implies tougher competition and a more pronounced effect of own output changes

[37]To support this claim, lower threshold values of product differentiation are needed under Bertrand competition. Comparing Wang/Yang (1999) and Wang (2002), who analyse an identical framework under either Bertrand or Cournot competition this is found to hold true.
[38]In the classical framework, no licensing occurs for the industry incumbent under Bertrand competition, while theoretical results on the superiority of ad valorem over per unit royalties are ambiguous. See San Martín/Saracho (2010) or footnote 14 in this paper for details.

on the price of the industry rival.[39] Additionally, in contrast to per unit royalties, licensee and inventor compete under equivalent marginal cost, following the transfer of the superior production technology for an ad valorem based contract. Therefore, by setting an optimal profit-based rate the patentee is able of appropriate the increase in production efficiency without distorting production levels. Combining these observations with the characteristics particular to Cournot and Bertrand competition, the former provide intuition for the following findings. While in a Cournot duopoly drastic innovations are transferred by means of a pure ad valorem contract, a combination of it with a fixed fee is preferred for non-drastic cost reductions, provided the degree of substitutability is sufficiently large. Under Bertrand competition Colombo/Filippini (2012) draw a different picture. The authors' conclude that per unit based rates are generally preferred to their ad valorem counterpart within the class of two-part tariffs. This result is illustrated drastically for significant cost reductions and products close to being homogeneous; in this instance no licensing is preferred to employing a value based royalty rate. Consequently, contrary to per unit based schemes, the previously cited empirical predominance of ad valorem based licensing contracts is not supported from the theoretical point of view.

To complement the analysis of Stackelberg competition within the homogeneous good framework, a final comment on this matter in the current setting seems appropriate. Comparing fixed fee and royalty based policies, a conclusion, similar to the one reached within the classical framework, is drawn; a per unit based contract is revenue maximising for the patentee, unless the degree of product differentiation together with the magnitude of cost reduction are sufficiently large. This results from the fact that in this instance, market profits of the inventor only decrease slightly as a result of the technology transfer via a fixed fee as products are reasonably distinct. Furthermore, when licensing a significant innovation, the willingness to pay of the potential licensee is large, creating an additional incentive for the diffusion of the superior technology. This brings with it that the loss in market share of the patentee, triggered by licensing to the follower, is minor compared to the benefit imminent in the increased efficiency of the rival. Thus, in a significantly heterogeneous product market, licensing via a fixed fee enables the inventor to *participate* in the market of the follower, without distorting production levels. This also contributes to explaining the discrepancy with respect to the result obtained in the absence of substitutability considerations, namely an absolute superiority of the licensing mechanism in question. The absence of differentiability, meaning a homogeneous product market, makes the prior described exception to the unanimous dominance of royalty based compensation schemes vanish. As a consequence, for a fixed fee mechanism the reduction in market profit more than outweighs the benefit in form of a more efficient licensee.
At this point one might wonder how to rationalise the diverging conclusions reached under Stackelberg and Cournot competition in the current context. To recall, under Cournot competition a per unit based policy is found to be superior, except for sufficiently differentiated products together with either minor or major cost reductions. This raises the question of why a fixed fee contract is preferred to a royalty based mechanism under non sequential quantity competition for minor cost reductions. To begin with, it has to be noted that due to the nature of the innovation, licensing revenues stemming from a per unit contract are small. What is more, under Cournot competition, the change in market shares triggered by the transfer of the technology is balanced, meaning a small increase in the licensee's market share goes hand in hand with a minor decrease in production levels of the patentee.[40] Consequently, the inventor is able to appropriate the increase in the licensee's efficiency, without experiencing a substantial decrease in market profit by employing a fixed fee based policy.

### 3.4 Spatial Competition

In the literature related to the study of horizontally differentiated products, a Hotelling structure as well as it various modifications represents a widespread modelling-choice. Incorporating it in the analysis of licensing agreements, new conclusions concerning the superiority of the single policies are reached. Presenting the latter is the purpose of this section. However, instead of elaborating on the single licensing schemes, attention is directed to how the introduction of spatial competition alters conclusion as well as intuition behind the equilibrium outcome. As the characteristics particular to the current framework are found to affect the inherent dynamics in a non-trivial way, a short discussion of the industry outsider environment adduces this subsection; introducing tradeoff considerations commonly shaping the industry insider case complements it.

To begin with, the focus lies on a linear Hotelling structure in which two firms compete *à la Bertrand.*

[39] Note that the framework defined in the beginning of this chapter implies an inverse demand function of the following form for agent one in a duopoly setting: $p_1 = a - q_1 - dq_2$; $p_1,\ q_{1,2}$ denoting price and quantity chosen by the respective agents.
[40] See Li/Yanagawa (2011)

Both agents are respectively located at the two end points of a closed interval, while consumers find themselves uniformly distributed over this line. Commonly, location is fixed, meaning it is not a choice variable of the single firm, in order to avoid the non-existence of an equilibrium in location due to the linearity of the consumer's disutility.[41] This brings with it that the object of investigation is a framework of maximally differentiated products and hence a model of high market power. Consumers are assumed to purchase one unit of the good, irrespective its price and, furthermore, to incur a disutility or transportation cost depending on the distance to either of the firms. It is important to note that products *per se* are homogeneous. However, via the spatial separation of consumer and firm, heterogeneity is introduced, making the products more or less desirable for the various consumers.[42] Later on the assumption of fixed end points is relaxed and firms are able to move symmetrically along the linear city.

**Comparing the Different Policies** Comparing auction, fixed fee and royalty based contract, a royalty mechanism represents the revenue maximising licensing option for an independent patentee. In contrast to the conclusion reached under either Cournot or Bertrand competition, any drastic or non-drastic innovation is licensed under full diffusion of the technology, while the per unit rate itself coincides with the magnitude of the cost reduction. This result partially relies on the specific features of the linear Hotelling model, for instance fixed markets size, implying a perfectly inelastic demand. This implies that the distortionary effect commonly associated with royalty licensing is no longer present and aggregate as well as individual production are unaltered.[43] Consequently, as prices remain constant, a higher surplus can be extracted by the patentee. What is more, should only one firm obtain a license, both firms operate under the same pre-innovation marginal cost. Thus, in either instance, market demand is split equally among the agents and licensing both firms is therefore superior.

How do things change for the industry incumbent? Poddar/Sinha (2004) show that non-drastic innovations are licensed via royalties, while for drastic cost reductions no technology transfer takes place. Similar to previous elaborations, competing on equivalent efficiency levels plays a large role in rationalising licensing, or rather its absence, from the incumbent to an industry rival. Moreover, with the inventor behaving rationally, the per unit rate is set such that output and licensing revenues approach zero for drastic innovations. Intuitively, in this instance, no technology transfer is a superior alternative.[44] Matsumura/Matsushima (2008) remark critically that in Poddar/Sinha (2002) the inventor solely maximises market profits and not total revenue on the last stage of the licensing game. Providing a model with quadratic transportation cost, the authors study a per unit based licensing contract under explicit derivation of the location equilibrium. Their findings reveal a royalty policy, in which rate and cost reduction coincide, as superior to the alternative of no licensing. What is more, firms choose the maximal differentiation and therefore the lowest competition. Also Kabiraj/Lee (2011) regard the work of Poddar/Sinha (2004) sceptically. One line of criticism concerns the constraint imposed upon the royalty rate, namely to not exceed the cost reduction in magnitude. Introducing an outside good in a linear Hotelling framework with fixed location they determine the optimal royalty rate endogenously. Restricting this rate to non-negative values and to provide full market coverage, technology transfer takes place for the chosen licensing mechanism, provided transportation cost lie in particular interval.

The analysis conducted in the present chapter conveys a unified picture; the concept of differentiated products appears fitting to model the empirically observed predominance of royalty licensing. This strongly suggests that the results derived in the classical framework rather have to be interpreted as an extreme outcome that cannot be supported in a more general setup. Here the critic might arise that while the analysis of the present chapter is conducted in terms of an incumbent innovator, the previous conclusions reached are based on an independent patentee. Nevertheless, in an oligopolistic framework of either Cournot or Bertrand competition, Bagchi/Mukherjee (2010) demonstrate the superiority of a royalty based compensation scheme for the outside innovator and a heterogeneous product market.[45]
In closing, a remark on the licensing income of the patentee. Everything else being equal, a market environment of homogeneous products is commonly perceived as more competitive with respect to its differentiated analogue in which monopoly like states can potentially be attained by the industry incumbents. Among other things, this shows itself in lower market revenue and higher (aggregate) production usually favouring per unit based policies. Nevertheless, in the homogeneous good framework, the auc-

[41] See d'Aspremont et al. (1979) for details.
[42] For completeness it is mentioned that in this setting a cost reduction is said to be drastic if, given only one of the two firms is licensed, the other agent is driven out of the market. As industry size is fixed this implies that the single licensee serves the whole market. With a line segment $[0, l]$ and transportation cost $t$ this implies $\epsilon \geq 3tl$ for drastic innovations.
[43] This holds true as long as the relative cost positions of the agents are unchanged.
[44] Employing a Salop model with two firms and consumers on the circle Poddar/Bouguezzi (2011) obtain similar results.
[45] Their results obtain under zero outside opportunity of the set of potential licensees and industry size sufficiently large.

tion mechanism is found to depict the profit maximising policy. This is rationalised with view on the introductory words of chapter two. What the patentee is able to exploit in form of licensing income is the degree of competitive interaction among the set of potential licensees. Keeping in mind that royalty licensing leaves the rival structure of the industry unaltered, *standing out from the crowd* can be understood as motivation behind fierce bidding behaviour within the homogeneous good environment. This observation not only rationalises the superiority of auction policies in the standard framework, but also suggests that licensing income in differentiated industries falls short the one attainable in a homogeneous product market. In a setting of monopolistic competition, shaped by heterogeneity affecting firm as well as informational structure, Hernández-Murillo/Llobet (2006), p. 162 reach a conclusion in favour of the prior statement; namely "*licensing proceeds should be higher in markets where firms produce a more homogeneous good because an innovation that reduces costs allows licensed firms to steal a larger market share from non-licensed competitors*".

# 4 Asymmetries

Up to this point the discussion evolved from an essentially symmetric setting. Reality, however, depicts a different picture; one rather has to assess the abundance of asymmetries inherent to the market or firm environment, readily translating into a heterogeneity of the informational structure. In the same vein, the majority of economic variables cannot be assumed to be known with certainty by all economic agents, but more as subject to expectation formation.
The consequence of introducing irregularities in form of sequential moves or product differentiation on the superiority of the single licensing policies is analysed prior to this section. What is novel in the present context, is the explicit acknowledgement of the latter phenomenon, namely that key quantities of the licensing game framework rather have to be interpreted as the realisation of a random variable, creating an informational gap between the set of potential licensees and the inventor.

To begin with, the difference between uncertainty and informational asymmetry is pointed out. Heterogeneity of the informational structure solely affects one side of the market, i.e. licensee or patentee, thereby creating a sort of imbalance. Uncertainty, on the other hand, impacts the game and its actors evenly. Although this work focuses on the former, uncertainty most certainly has a non trivial impact on the superiority of the licensing mechanism. In this context, it is worth naming Jensen (1992), who observes predominance of fixed fee over auction by introducing uncertainty, related to the success of the technological advance, as well as finite patent protection. In the framework, the transfer of the innovation reveals the true state as common knowledge and thus provides the non-licensee with a *second mover advantage*. Bousquet et al. (1998) concern themselves with a type of uncertainty affecting demand or cost structure of the industry. The authors conclude that all instruments considered, namely per unit or ad valorem royalty as well as fixed fee, may be employed in the equilibrium contract, depending on the explicit parameter constellation.

The second remark pertains to the type of asymmetry the present chapter puts focus on. As indicated in its title, this work directs special attention towards the particular role of market structure on the superiority of a licensing mechanism. That is why it abstracts from the question of how heterogeneous information concerning the value of the innovation potentially alters the licensing game, and concentrates on how informational irregularities of the market structure itself impact the optimal compensation mechanism. For further reference the reader might turn to Gallini/Wright (1990), who study the case of a licensor possessing private information concerning the magnitude of cost reduction embodied in the innovation. Conversely, Hernández-Murillo/Llobet (2006) analyse a framework of monopolistic competition in which the licensees are equipped with private information regarding the value of the technological advance. In the same vein, Beggs (1992) provides rational for the empirically observed predominance of royalty licensing.

As the reader might conjecture when reading the introductory part of this chapter, the particularities inherent to the present framework necessitate a restatement of the licensing game. Before doing so, a remark on the characteristic features of the industry is appropriate. Focus lies on the interaction between the independent patentee and a single potential licensee, holding the monopoly position in the market. This brings several, non trivial implications with it. Firstly, related to a similar remark concerning the industry incumbent duopoly framework, auction and fixed fee based schemes coincide in the eyes of the revenue maximising patentee. Consequently, without loss of generality, attention is directed towards

fee, royalty or two-part tariff licensing.[46] Finally, rejecting the contract offered, the firm, employing the inferior production technology, is able to attain its monopoly profit. This gives a significant degree of *bargaining power* to the potential licensee. All in all, it makes sense to focus on the industry outsider case. A lack of information concerning the market structure is only hard to reconcile for the patentee being an incumbent to the industry.
On the first stage of the game, a third player enters the picture; namely nature, which, in the present context, draws either cost of production or demand from a common probability distribution.[47] For the sake of simplicity it is assumed that the values taken are dichotomous, i.e. of either *high* or *low* type. While the actual realisation remains private information of the firm, the patentee is characterised by his prior belief about it. Specifically, the inventor assigns a certain probability to either of the two events, where the belief is common knowledge of all agents; we are in a game of adverse selection. This, together with the absence of monitoring possibilities, provides the agent characterised by a beneficial parameter constellation, meaning high demand or low cost, with an incentive to mimic his mirror image as in doing so, licensing expenditures are mitigated. On the second stage, the patentee offers a single or several distinct contracts, subsequently either accepted or rejected by the potential licensee. In determining the optimal contract, the patentee faces the choice between a non-discriminatory (pooling) or discriminatory (separating) scheme. This implies that the contract is respectively independent of the potential licensee's attributes or designed such that it is exclusively accepted by either type. In the last instance, the patentee offers a menu of contracts; one for each type of agent. Thereafter, on the last stage of the game, the contract is executed and revenue maximisation determines the common equilibrium quantities.

The following paragraph concerns itself with a more precise description of the various contracts as well as their optimality, depending on the nature of the compensation scheme. Hereby, the example of informational asymmetries affecting industry demand is employed, followed by a comment on the conclusions reached in a setting in which the cost structure is subject of the former. Two remarks in advance; directing attention towards process innovations, the randomness of the demand structure stems from a parameter out of reach of the licensee. Varying levels of efficiency within the industry, however, may, among other things, be traced back to diverging decisions concerning the newness of technology in the interfirm context. What is more, heterogeneity in the demand structure primarily affects the optimal fixed fee, while distinct marginal cost predominantly impact the royalty rate.

**Pooling Contract** From the previous analysis it can be inferred that, neglecting for a moment the presence of asymmetric information, the fixed fee set by the patentee coincides with the difference in monopoly profits triggered by implementing the superior technology in the production process. In the present context, however, the precise value of the discrepancy is subject to speculation as the demand situation of the industry constitutes private information of the firm. Demanding a fee based on low market demand, both type of agents accept the contract. The reverse situation, meaning a fee corresponding to high market demand, is characterised by the exclusive agreement of the high type. To circumvent this inefficiency imminent to adverse selection, the patentee maximises expected licensing revenue, weighing the type dependent fixed fee income by its respective probability. This strategy is shown to result in a threshold value of probability such that for a prior belief (of meeting a low type) exceeding it, a minor fee is demanded and vice versa. As a corollary, the innovation experiences no diffusion with a positive probability, in case demand is minor ex post within the latter regime.
Also in the class of two part tariffs the contract offered is uniform across types. However, due to the fact that royalty payments are positively linked with industry demand, transferring the technology to a high type is beneficial in terms of licensing income. Engaging in (expected) revenue maximisation, while respecting the type dependent participation constraints[48] a threshold value is obtained that divides the parameter space of prior believes in two distinct intervals. In the first regime, meaning a minor probability is assigned to the event of low demand, the familiar equivalence of per unit rate and magnitude of cost reduction is observed. Conversely, if the likelihood of strong demand is evaluated as sufficiently high, the optimal contract involves positive fee and royalty rate. Hereby, the rate accommodates the patentee's

[46]There might be another reason of why to abstract from an auction based mechanism. In a framework shaped by incomplete information with a single outside patentee and an oligopolistic industry characterised by price competition, Moldovanu and Sela (2001) demonstrate that a standard auction mechanism allocates the license to an arbitrary firm in a pooling equilibrium allocation, i.e. is not efficient from a social point of view. Similarly, Das Varma (2003) observes the potential non-existence of an efficient equilibrium outcome under Bertrand competition, while uniqueness is derived in a competitive environment *à la Cournot.*
[47]This idea follows Harsanyi's (1967-1968) work on games with incomplete information. In order to analyse games in which certain actors are not equipped with full information concerning the rules of the former, the original game is replaced by one in which "*nature first conducts a lottery in accordance with the basic probability distribution, and the outcome of this lottery will decide which particular subgame will be played* [...]". Harsanyi (1967), p.159.
[48]Meaning the licensees' post transfer revenue net licensing expenditure has to exceed their outside option.

prior belief as well as the discrepancy between both demand situations.
Comparing the single compensation schemes based on the patentee's expected licensing income, it is observed that for sufficiently favourable demand prospects a pure fixed fee contract, *targeted* at the high type, is offered (*shutdown* of the low demand type). In the reverse situation, a two part tariff, acceptable to both agents is offered. Owing to the more pronounced flexibility of a two part scheme, the present threshold of prior belief falls short of the one associated with a pure fixed fee policy. As a corollary, the inefficiency in form of no technology diffusion is mitigated.
How do things change if the marginal cost structure is private information to the firm? Again, in a complete information framework, setting fee and royalty rate in order to extract the entire monopoly revenue via a two part tariff is optimal in the eyes of the licensor. However, if those instruments are derived with view on the low cost type, the previously addressed inefficiency shows itself in form of an absence of licensing in case a high cost agent is drawn. In this context, Sen (2004) observes a coexistence of the various policies, depending on magnitude of cost reduction and prior belief of the patentee. For incremental innovations, together with a minor probability assigned to the event of a low cost firm, a two part tariff *targeted* at the high cost type is proposed; if the likelihood is assessed as more pronounced, a classic pure royalty contract dominates. Finally, for a sufficiently strong belief, a fixed fee based policy *aimed* at the low cost type serves as the revenue maximising scheme. For technological advances of larger magnitude, the proposed pooling contract takes on a similar form, except that the regime characterised by an intermediate subjective likelihood vanishes.

**Separating Contract** As previously mentioned, a pooling allocation endows the high demand type with incentives to mimic its low demand analogue in order to reduce the burden of licensing expenditures. This clearly represents an inefficiency in form of lost revenue from the perspective of the licensor. Constraining the optimisation problem in such a way that only incentive feasible allocations remain, several distinct contracts, involving instruments indexed on the type, are optimally offered. In particular, this requires net profit of either demand type to exceed the one obtained by switching the contract specific subscripts. Note that parameters defining the true environment remain unaltered. With view on the optimisation problem it becomes apparent that due to the informational advantage the patentee has to transfer a rent to the type of agent characterised by an advantageous parameter constellation, unless this agent's mirror image is *shut down.* Again, the result is a threshold value dividing the space of prior believes into two regimes. However, in contrast to the previous form of allocation, the optimal contracts are heterogeneous across types. Here, for a minor likelihood of weak demand, the low type faces a pure royalty contract, characterised by equality of per unit rate and cost reduction. In contrast, its counterpart is offered a pure fixed fee scheme. In the complementary interval, the per unit rate, now applying uniformly to both agents, falls below the magnitude of technological advance; fixed fees related to low or high type in-or decrease receptively, compared to the prior regime.
Also for an asymmetric cost structure the equilibrium menu of separating contracts is diversified across types. In this context, a minor belief associated with a low cost type goes hand in hand with setting a fixed fee for the latter and proposing a two part tariff for the opposite agent. For a more pronounced subjective probability, the contract offered to the low cost agent is unaltered, while the scheme targeted at the high cost type collapses to a pure royalty contract.
As it is insinuated throughout the paragraph, a separating allocation yields the highest licensing income to the patentee. What is more, regardless the patentee's judgement concerning industry demand or cost structure, the technology is potentially transferred.

Concluding, it can be asserted that in the class of non-discriminatory allocations the optimal licensing contract leads to a *shutdown* of the type endowed with the least favourable characteristics, in case market or firm environment are assessed as sufficiently beneficial. If the patentee is able to employ a discriminatory scheme, the technology experiences full diffusion and contracts are similar across the various types of asymmetries. What is more, if the prognosis of the relevant parameters turns out to be predominantly negative, a two part tariff is chosen as compensation scheme in either class of contract. This can be rationalised with the observation that two part tariffs provide an optimal arbitrage mechanism concerning the sources of asymmetric information that are presented here. Choosing pure fixed fee licensing, a switch to a per unit based scheme is beneficial in case demand is low and production cost therefore relatively high. Conversely, licensing income stemming from a pure per unit based policy falls short of the one attainable under fixed fee licensing in a situation of strong market demand. Conducting a similar thought experiment for a heterogeneous cost structure, an equivalent result is found to hold true. In the same vein, offering a contract involving either of the two instruments is rationalised for the class of separating agreements.

## 5 Conclusion

What conclusions can be drawn from this review of the literature portraying the theoretical advances related to the analysis of licensing behaviour, and, even more important, what practical relevance do the results obtained have?

First of all, the common wisdom concerning the superiority of license auctions from the perspective of a revenue maximising patentee has to be given up. As soon as additional considerations are taken into account, the pattern found within the classical framework is altered, predominantly in favour of a policy involving royalties. What is more, this form of compensation scheme rather has to be interpreted as a theoretical artefact, bearing little relevance in the inter firm context. Also the literature seems to turn away from analysing licensing in an auction based framework by predominantly focusing on settings in which this policy coincides with alternative schemes. The mitigated practical irrelevance is aggravated by the fact that the theoretical contributions reviewed, unanimously ignore the cost associated with the implementation of a licensing mechanism. However, especially in the context of an auction based policy, those costs are perceived as being non trivial and hence commonly necessitate the involvement of a third party, for instance the government.
Secondly, if it is the policy makers objective to maximise diffusion of the new technology while simultaneously minimising restrictions imposed upon the patentee it appears optimal to reduce the set of licensing instruments available to royalties; engaging in revenue optimisation the patentee *mechanically* licenses to the entire industry, unless the innovation is drastic. Moreover, the structure of the market remains essentially unaltered. As a consequence, a commitment to this policy might be of particular use for unstable or highly dynamic industries in order to not perturb them additionally. Further, it has to be remarked that per unit or ad valorem payments serve as an arbitrage mechanism. As a corollary, during an economic downturn, companies are unburdened as the associated decline in production is accompanied by reduced licensing payments. This, however, also entails a negative implication. Namely, during a phase of economic progress, licensees are not able to fully reap the rewards as the burden in form of licensing expenditures increases proportionally. Another detriment inherent to this licensing policy has to be addressed at this point. In an increasingly global business environment, issues associated with verifiability of production or revenue experience aggravation. In return, associated costs may make a royalty mechanism less desirable for the patentee, unless equipped with more potent rights concerning the disclosure of relevant information.
In this context, it should be noted that an informational gap between licensee and patentee additionally has the potential to generate an inefficiency in terms of the diffusion of the novel technology. Thus, promoting new standards necessitates thinking about ways of breaching this heterogeneity, without significantly harming either party involved. As a corollary, a close understanding of the market environment is essential and licensing via an industry incumbent beneficial. In this instance, employing royalty based schemes provides the highest incentives for research and development, while simultaneously ensuring maximal diffusion.
Next, to ease progress of young firms within an industry characterised by competition among a few established players, a fixed fee contract is optimally employed. Thereby the newcomer is endowed with an efficiency advantage. Moreover, for intermediate market size the industry is characterised by a mixed technology; hence, all in all the competitive climate increases. In general, in (young) industries characterised by fierce competition, the here discussed compensation scheme is superior for the independent patentee. Additionally, the market itself benefits from the absence of the distortionary effect on aggregate production associated with a royalty contract and is able to develop optimally. Note that for more developed industries this effect is absent and maximal diffusion of the innovation can be attained without distorting output by employing a per unit based mechanism.
Finally, it has to be pointed out that measures aimed at increasing the degree of competition within an industry affect incentives concerning research and development positively as long as either fixed fee or per unit rate are employed. Thus, restricting licensing contracts to those instruments is compatible with antitrust related policies. In any other instance, research runs the risk of being aimed at highly concentrated markets, involving the almost exclusive transfer of the advanced technologies.

Concluding, a critical remark has to be made. Despite the vast amount of research on licensing behaviour, the latter is still in its infancy concerning its closeness to reality. In order to obtain a better feeling for licensing related matters, additional aspects need to be considered. Evidence is augmenting that not only revenue maximisation, but also strategic considerations (e.g. entry deterrence, continued supremacy in a market) drive the action of both parties involved. Further, the role of independent companies, managing patent portfolios deserves special attention. Representing the interests of the inventor, their presence bears the potential of distorting the equilibrium outcome. Last, the literature reviewed implicitly assumes that all licensees benefit similarly from the technological advance, i.e. are endowed with a comparable standard of technology prior to the transfer. It is obvious that this stands in stark contrast to reality and might have a non trivial impact on the superiority of the various licensing schemes.

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# A Appendix

## A.1 Figures

Data underlying this section is publicly available at http://data.worldbank.org

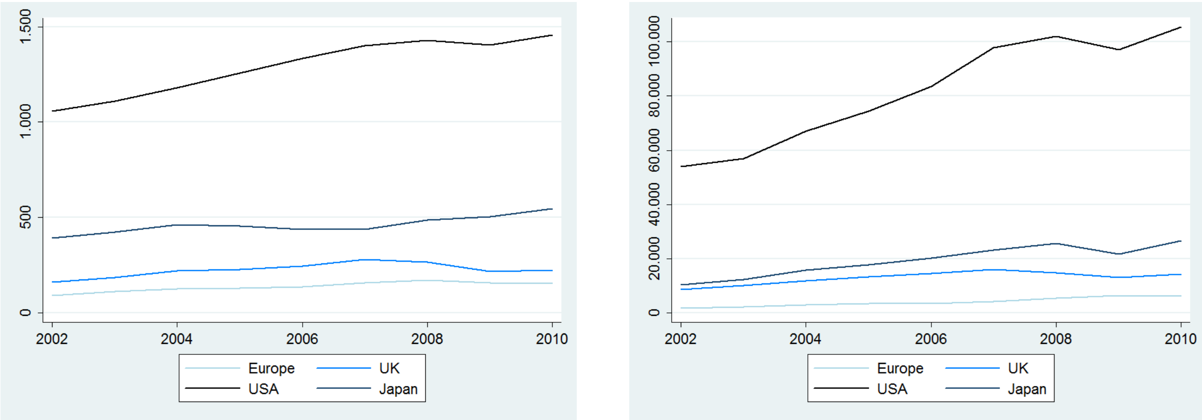


Figure 1: Gross Domestic Product/Licensing Receipts, in Billion/Million US-Dollar

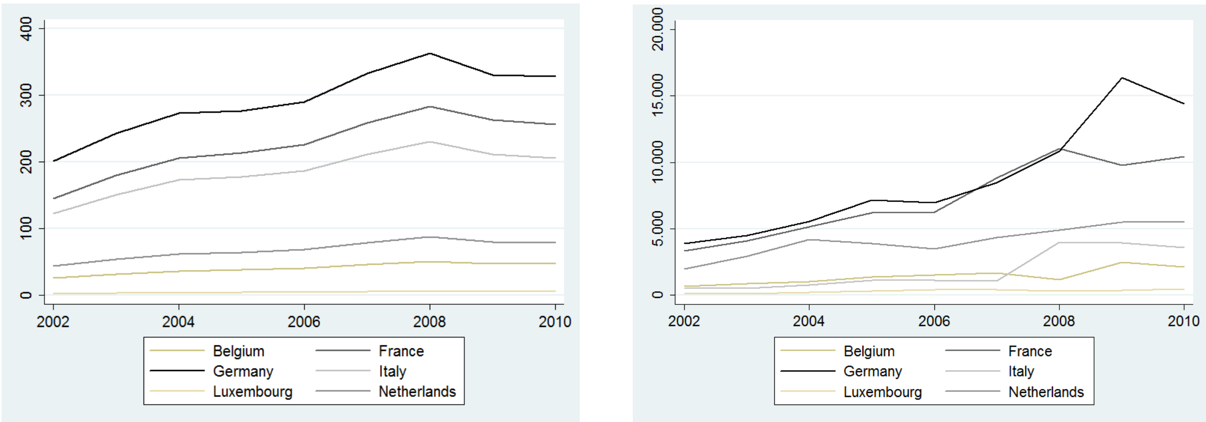


Figure 2: Gross Domestic Product/Licensing Receipts, in Billion/Million US-Dollar

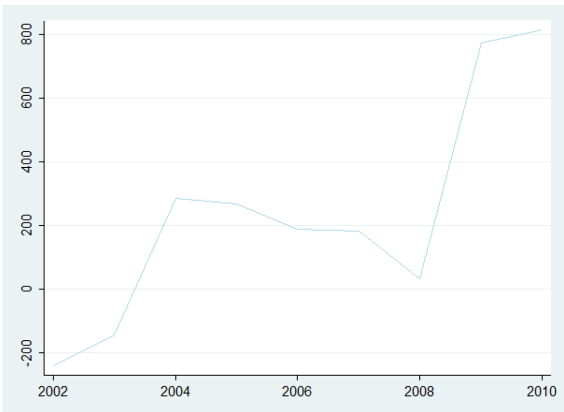


Figure 3: Aggregate Net Licensing Receipts (Belgium, France, Germany, Italy, Luxembourg, Netherlands), in Million US-Dollar

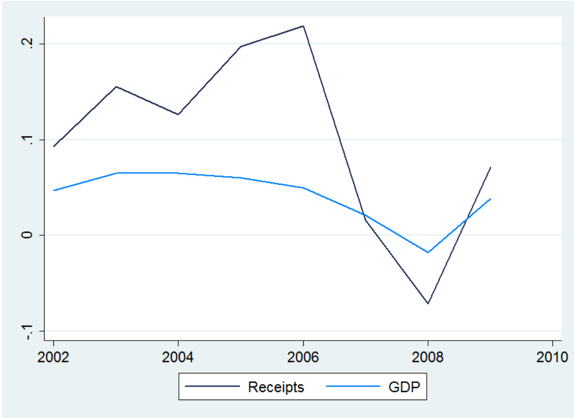


Figure 4: Growth Rate Gross Domestic Product USA/Net Licensing Receipts USA

### A.2 The 3-Stage Licensing Game in the Classical Framework

**STAGE 1: The Patentee's Optimisation Problem (Licensing Revenue Maximisation)**

| Auction Policy (A) | Fixed Fee Policy (F) | Royalty Policy (R) |
|---|---|---|
| $\max_{1\leq l\leq n} \pi_P^A = lb$ | $\max_{1\leq l\leq n} \pi_P^F = lf$ | $\max_{0\leq r\leq \epsilon} \pi_P^R = Qr$ |

Variables determined on stage 1: $l^{j,*},\ \pi_P^{j,*};\ j \in \{A, F, R\}$

$$\Updownarrow$$

**STAGE 2: Determining the Demand for Licenses (Maximal Willingness to Pay)**

| Auction Policy (A) | Fixed Fee Policy (F) | Royalty Policy (R) |
|---|---|---|
| $\pi_{i,L}^A(n,l) - \pi_{i,NL}^A(n,l) = b_i = b$ | $\pi_{i,L}^F(n,l) - \pi_{i,NL}^F(n,l-1) = f_i = f$ | $r = \epsilon \mid r = p_m$ |

Variables determined on stage 2: $b,\ f,\ r$

$$\Updownarrow$$

**STAGE 3: The Firms' Optimisation Problem (Market Revenue Maximisation)**

| Set of Licensees (L) | Set of Non-Licensees (NL) |
|---|---|

$$\max_{q_i} (p - c_i)q_i - F_i$$

| Set of Licensees (L) | Set of Non-Licensees (NL) |
|---|---|
| Auction Policy (A) | Auction Policy (A) |
| $c_i = c - \epsilon$ | $c_i = c$ |
| $F_i = b_i$ | $F_i = 0$ |
| Fixed Fee Policy (F) | Fixed Fee Policy (F) |
| $c_i = c - \epsilon$ | $c_i = 0$ |
| $F_i = f_i$ | $F_i = 0$ |
| Royalty Policy (R) | Royalty Policy (R) |
| $c_i = c - \epsilon + r$ | $c_i = c$ |
| $F_i = 0$ | $F_i = 0$ |

Variables determined on stage 3: $\pi_{i,L}^{j,*},\ \pi_{i,NL}^{j,*};\ j \in \{A, F, R\}$

| | |
|---|---|
| $b,\ f,\ r$ | bid, fee, royalty rate demanded by the patentee |
| $c$ | marginal cost of production |
| $\epsilon$ | magnitude of the cost reduction |
| $F_i$ | non-variable cost associated with obtaining a license |
| $l$ | number of licenses offered by the patentee |
| $p_m$ | monopoly price |
| $q_i,\ Q$ | individual, aggregate industry production |
| $\pi_{i,L}^{j,*},\ \pi_{i,NL}^{j,*},\ \pi_{i,P}^{j,*}$ | market revenue of licensee (L), non-licensee (NL), patentee (P) in dependence of licensing policy $j$ |

Figure 5: The 3-Stage Licensing Game