License Expenditures of Incumbents and Potential Entrants: An Empirical Analysis of Firm Behavior

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Abstract

This paper presents the results of an empirical test concerning the auction model of Gilbert and Newbery (1982). The study uses data on German companies in order to analyze expenditures for technology licenses. Aside of standard control variables the motives for innovation expenditures are also taken into account. We differentiate between firms which intend to secure their present position in the market (incumbents) and those intending to enter a new market (challengers). In line with the prediction of the auction model, it turns out that incumbents show higher expenditures for technology licenses than potential entrants.

Keywords: Innovation, Licenses, Incumbent versus entrant, Limited Dependent Variables

JEL-Classification: L12, O31, O32

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1 Introduction

Empirical literature on innovation produced a broad knowledge about determinants of R&D (intensity) and patenting behavior at the firm level. Sales realized by newly developed products and innovation counts are also considered, but less frequently. There are, however, further aspects of innovative activity. Many innovations are not exclusively used by one firm (the inventor), but are licensed for use by others. This is also reflected in numerous theoretical articles on technology licensing. Nevertheless, empirical studies on this subject are very rare. This paper discusses theoretical results on the incentives to purchase licenses, and it aims at deriving empirically testable hypotheses based on economic theory. We subsequently report the results of an econometric study on the determinants of licensing expenditures.

Much has been written about the discussion concerning the incentives of a monopolist compared to a potential entrant to invest in innovation since the seminal contributions of Schumpeter (1934, 1942) and Arrow (1962). More recent papers use game-theoretic approaches to analyze this question. Basically there are two rivaling models: the patent race model (cf. Lee and Wilde, 1980, Reinganum, 1983, 1984, 1985, among others) and the auction model of Gilbert and Newbery (1982).

The patent race model highlights uncertainty and time during the innovative process. Firms compete in R&D projects and the successful innovator obtains a patent, which in turn is connected with a given profit (the price). In this scenario the incumbents invest less in R&D than a potential entrant (the challenger), as a successful innovation would replace the current monopoly and the profits from it would be dissipated. In contrast, the challenger currently has no profits (in that market) and hence this R&D-reducing effect does not exist for it.

The auction model of Gilbert and Newbery (1982) assumes that a process innovation has already been invented and now the license for its use is offered to a monopolist and a potential entrant. As time plays no role and the profit to be gained from its application is known, the uncertainty factor is absent. If the innovation is non-drastic, the monopolist will offer more than the potential entrant, and if the innovation is drastic, both will pay the same.

Thus, the predictions of these two models differ. Czarnitzki and Kraft (2004) consider the behavior of firms in the R&D process and find that potential entrants invest more in R&D than incumbents, i.e. the predictions of the patent racing model are supported. Lerner (1997) explicitly tested for racing behavior in the disc drive industry. He also reported that the patterns found are in accordance with Reinganum's work: firms that trail the leader innovate more. However, rather than analyzing innovation input (e.g. R&D expenditure) he investigates the timing of innovation. For example, he considers the "progress made by firm company in density (MB/in^2)" (Lerner, 1997: 240) over time, or looks at "time until firm's next introduction of an improved drive" (Lerner, 1997: 241). While this is a very interesting study on the innovation process in the disc drive industry, Lerner does not directly test for innovation incentives of incumbents and challengers. Although there might be a high correlation between investment in innovation and its outcome, since inventing is a highly uncertain process, this does not necessarily have to be the case.

It is important to note that the auction model considers a technology that has been invented by another party outside the market and it does not consider R&D. Therefore, Czarnitzki and Kraft (2004) state that there is a gap between this theory and the empirical study, because the analysis of R&D might be inappropriate for testing the Gilbert and Newbery (1982) model. The auction model may have its relevance for innovation projects that are not as risky as R&D activities. If licenses are bought or a new technology (from outside) is introduced, the risk involved is presumably much smaller than that of an R&D process. There have been no tests to date as to whether the Gilbert and Newbery model applies to such investments in innovation.

Our empirical study aims at the analysis of licensing expenditures of companies. Empirical research concerning licensing is very rare. To the best of our knowledge we are the first to perform an econometric test on the relationship between the position of the firm in the market and its licensing expenditures. One reason for this is possibly the difficulty of obtaining relevant data. The following section gives a brief literature overview and the third section describes the database and presents the empirical setup as well as estimation results. The final section concludes.

2 Theory

Numerous theoretical contributions discuss the impact of strategic considerations on innovative activity. Firms take into account how competitors will react in response to their own behavior and how this will affect equilibrium in the industry. A very prominent example is the impact of market power, but the discussion in existing literature is controversial. Since the seminal contributions by Schumpeter and Arrow, models have predicted quite different results concerning the role of the incumbent versus that of the challenger. Basically there are two approaches in existing literature: the auction and the patent racing models.

The second kind of modeling uses stochastic racing models. Important elements of the models are uncertainty and time. Firms compete in R&D projects for an invention and the development of an innovation. The period until discovery and introduction of the innovation is of random length, but depends on the level of R&D, since with greater expenditure the probability of success increases. There is a basic asymmetry, because the incumbent currently draws profits from the market in which it is operating, while the challenger does not (by definition). In this situation the incumbent has a lower incentive for R&D as this would reduce the time period until success and its current profits would disappear. The incumbent would substitute itself, while the challenger has no such considerations in mind.

The auction model by Gilbert and Newbery (1982) has very different assumptions and predictions. In this setting an incumbent is faced with potential competition by challengers which are currently outside the particular market in question. The incumbent and the challenger(s) bid for a process innovation. If the challenger were to win, market entry would take place. Thus, in this model there is no time dimension, because the auction takes place today and the process innovation is immediately implemented. Uncertainty is also absent, because the value of the innovation is known, and the highest bidder gets the innovation. (In the patent race model the firm with the largest expenditure for R&D has the highest probability of success but no guarantee.) With these assumptions in the auction model, the incumbent bids more in the case of a non-drastic innovation and both bid the same amount in the case of a drastic innovation. The result is driven by entry-preemption motives.

Of course, there has been a discussion on the assumptions of the Gilbert-Newbery model and some alternatives have been offered. The incentive for preemptive patenting and persistent monopoly in the Gilbert and Newbery (1982) model comes from the reduction of profits if the industry becomes less concentrated. Salant (1984) discusses the impact of licensing on this result. If licensing is possible, the most efficient firm will win the patent. Then the winning firm may sell the patent to the other firm, if this one is a more effective producer. Optimal licensing will lead to a monopolized market, but the innovator must not necessarily be the incumbent.

Krishna (1993) studies sequential auctions of capacity, and monopoly may not persist in this situation. Chen (2000) shows that the incentive for bidding for a new product depends on the relation to the existing product of the monopolist. The monopolist tends to win the bidding if the two products are strategic complements. In contrast, the potential entrant will offer more if the two products are strategic substitutes.

A quite restrictive assumption of the Gilbert and Newbery model for the empirical relevance is that just one incumbent and also just one potential entrant are considered. In practice almost no market is monopolized, aside of regulated industries. With an oligopolistic industry and potential entry in principle, the number of licenses has to be endogenously determined according to the revenue maximization aim of the innovator.

Licensing theory analyses the determination of the optimal number of licenses. This strand of literature, however, ignores the possibility of entry. Kamien (1992) surveys the results concerning licensing behavior of patentees. In the case of a drastic innovation, the efficiency effect points to the conclusion that the monopoly profit is larger than, or equal to, the sum of the duopolists' profits. The inequality will be even more pronounced in the case of wider oligopolies. Then the innovator should just issue one license.

However, this reasoning is limited to drastic innovations (Kamien, 1986) and does not hold true for non-drastic innovations. In this case more than one license is traded, but the patentee restricts the number of licenses. He or she never licenses more firms than the number for which the Cournot equilibrium price equals the perfectly competitive price with the original, inferior technology. If the invention is non-drastic the number of licensees is at least equal to one-half of the number of potential licensees. By use of the example of a process innovation, Kamien (1992) demonstrates that the exact number of licenses depends on the degree of reduction of the unit production costs. With small cost reductions, all firms in an industry obtain licenses. If the magnitude of the unit cost reduction increases somewhat, not all firms will obtain licenses, but all (whether unlicensed or licensed) will continue to operate in that particular industry. If the cost reduction is sufficiently large, the number of firms in the industry is reduced to the number of licenses. Concerning the question of how to sell the licenses, Kamien (1992: 334) concludes: "In general, auctioning licenses, that is, offering a fixed number of licenses to the highest bidders, yields the patentee a higher profit than offering licenses at a fixed fee or royalty rate to any firm willing to purchase one."[1]

Arora and Fosfuri (2003) consider the case where incumbent firms license their technology to potential competitors. Although it initially appears surprising that an incumbent issues licenses at all, this may happen if one or several other incumbents are active in the same market. When other firms are also able to supply the product, licensing enables a firm to expand its market share at the expense of the other producer(s). A counter effect to licensing is the price-reducing effect of the existence of more competitors. It depends on the specific parameter values whether the benefits from an extended market share outweigh the losses from increased competition or not. Arora and Fosfuri are, however, not able to solve explicitly for the optimal number of licenses.

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[1] The analysis can be enlarged by comparing an outside inventor with an incumbent inventor. Kamien and Tauman (2002) show that an outside inventor maximizes profits by targeting greater cost-reducing inventions to monopolistic industries while an incumbent inventor prefers competitive industries.

In conclusion, in most cases the number of licenses is below the number of firms which could, in principle, use the license. Therefore a bidding process for the offered licenses must take place which determines the number of licensees and the licensing expenditures of the successful firms. If the Gilbert and Newbery model generalizes to the situation with more than one incumbent and more than one potential entrant, the incumbents will pay more. If this model is not suited for oligopolies, we will either find no difference between firm types or that the entrants offer more for a license.

3 Empirical Study

In this section, we investigate who spends more on licenses, the incumbents or potential entrants. Although a number of theoretical papers discuss this issue, there are very few empirical articles on this topic. Earlier empirical studies on licensing investigate the determinants for the existence of licensing contracts in general. Anand and Khanna (2000) consider differences between industries, Link and Scott (2002) investigate which patents are licensed to whom, and Vonortas and Kim (2004) study, among other factors, the impact of proximity of firms defined as technological and market closeness. Anand and Khanna (2000) find significant differences between industries and discuss the results on the basis of the strength of property rights. Link and Scott (2002) show that the probability of licensing increases with a potential licensee's patent citation referring to prior art of the potential licensor. Vonortas and Kim (2004) show that firms with closer technological and market profiles, as well as those active in industries with strong intellectual property protection, engage more often in licensing agreements. Since Vonortas and Kim as well as Link and Scott analyze the type of licensing partners, taking these studies into more detailed account is beyond the scope of this paper, because we have no information on the pairs of contractors in our data. However, we refer to the basic findings of Anand and Khanna and model industry differences by employing a set of dummy variables in all regressions.

3.1 Data

This study uses data from the Mannheim Innovation Panel (MIP) which is an innovation survey conducted by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry for Education and Research (BMBF). The MIP survey has been carried out annually since 1993. In 1993, 1997, 2001 and 2005 it represented the German part of the Community Innovation Survey (CIS) of the European Commission.

As the questionnaire of the MIP has changed over time, we can only use the surveys from 1993, 1994 and 1996, i.e. the data corresponding to the years 1992, 1993 and 1995. Our random sample covers German manufacturing firms with at least ten employees and consists of 3,814 observations applying to 2,664 different companies. The panel structure of our dataset is highly unbalanced: 73% of the companies were only observed in one of the three years, about 20% were observed twice, and only 7% were observed in all three periods. Therefore, we cannot conduct panel econometric analyses, but only pooled cross-sectional regressions.

The sample can be divided into three groups: 1,644 observations refer to non-innovating firms. The other 1,915 observations refer to firms that show at least some innovative activity. An innovating company is defined according to the guidelines of the "OSLO Manual":

> "Technological product and process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organisational, financial and commercial activities. The TPP innovating firm is one that has implemented technologically improved products or processes during the period under review." (Eurostat and OECD, 1997: 47).

Within the group of innovating firms, we can identify firms that purchase licenses. First, innovating firms are requested to indicate their total innovation expenditure

(*TOTINNO*)[2] in the questionnaire of the MIP. In the subsequent question, respondents provide the distribution of the total spending on different subcategories. Among others, firms fill in the "expenses for the purchase of licenses and similar usage rights". We use this variable in the upcoming analysis and call it *LICENSE* henceforth. In the sample, only 396 observations show license expenditures larger than zero. The majority of firms did not buy any license in the observed time periods.

We consider three different specifications of the dependent variable in order to test the robustness of the results: First, we use the amount of license expenditures in EUR million (*LICENSE*). Second, we consider the licensing intensity with respect to sales (*LICENSE/SALES*), and third we also consider the ratio of license expenditures to total innovation expenditures[3] (*LICENSE/TOTINNO*). As these variables exhibit a high skewness in distribution, we prefer to use a log transformation in the upcoming regression analysis. In order to take the log of these variables, we set the zero values to the minimum of the observed positive license expenditures. The bias arising from this should be very small, because we just interpret the one observation with the minimum non-zero value as censored observation with no license expenditure.

A major advantage of our data source is the information on the motives for R&D activities. We are able to consider potential entry, which possibly never leads to actual entry. If the Gilbert and Newbery (1982) model is true, an entrant will not win the bidding on a scarce license (if not every firm gets a license) and therefore intended entry will not lead to realized entry. Our data is thus very different from that of other studies analyzing the effect of observed and successful entry, but not the attempts to enter.

In particular, the MIP questionnaires asked the firms for their motives for conducting innovative activities: “With product and process innovation a number of different

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[2] Total innovation expenditure is defined according to the OSLO Manual. It comprises current and capital expenditure, in particular: R&D expenditure; expenditure for the acquisition of disembodied technology and know-how; expenditure for the acquisition of embodied technology; expenditure for tooling up, industrial engineering, industrial design and production start-up, including other expenditure for pilot plants and prototypes not already included in R&D; expenditure for training linked to TPP innovation activities; marketing for technologically new or improved products (see Eurostat and OECD, 1997: 87).

[3] For non-innovators we set this expression to the minimum value which is zero.

aims can be followed. We would like to know more about the most important motives for the innovation decision and the innovation strategy of your company." This question is followed by a list of different aims whose importance can be ranked on a five-point Likkert scale by the respondents from "not important" to "very important". One possible response to this question is particularly about the entry into new markets: "the enlargement of the products outside of the main markets you are operating in."[4] If a respondent indicated that this aim is of very high importance (rates it with 5), we code this as the unit value of a dummy variable called *ENTRY*. Otherwise *ENTRY* is zero.

Another alternative among the motives for innovation is the importance of securing and increasing the current market share. The firms respond again by use of a five point scale. We use this variable to define incumbent firms. The dummy variable *INCUMBENT* has unit value if a firm puts a very high importance on this aim, i.e. uses the maximum scaling possibility of 5.

The Gilbert-Newbery theory is based on the distinction between drastic and non-drastic innovations. For drastic inventions, both the incumbent and the potential entrant would bid the same amount for the invention. In the case of non-drastic inventions, the incumbent would offer more. Unfortunately, we are unable to identify drastic and non-drastic innovations in our data, but we can assume that the data most likely reflect a mixture of drastic and non-drastic inventions. Therefore, if the Gilbert-Newbery model were to be true, it should still be possible to identify different behavior of incumbents and potential entrants with respect to license purchases.

Another problem for empirical work is that theory usually discusses process innovation, but not product innovation. We have no information about the purpose of the license expenditures.

In addition to the variables identifying incumbents and potential entrants, we include several control variables. Firm size is specified as the log of the number of

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[4] This does not include the geographical expansion of markets. Geography is explicitly concerned in separate questions.

employees (ln*EMP*). This variable controls whether innovative activity varies with firm size and therefore takes account of the classical Schumpeter hypothesis.

We control for both competition by domestic sellers and foreign manufacturers: the concentration of domestic sellers (*HHI*) is defined as the Herfindahl-index on the three-digit NACE industry level. It is the sum of squared market shares of the firms operating in the three-digit industry (multiplied by 1000). One problem is that in Germany the basic classification of industries changed in the nineties from the SYPRO to the European NACE standard. The MIP classifies companies according to the NACE standard, but the German statistical office has been publishing a Herfindahl index on the basis of NACE only since 1995. We transformed the data from SYPRO statistics to an index on the basis of the NACE standard for 1991 and 1993 (and calculated averages for the years in between). The related measure for foreign competitive pressure is sales of foreign firms compared to total sales of both foreign and domestic firms in an industry at the two-digit industry level, which is called *IMPORT* [= imports / (domestic production + imports)*100]. This variable is expected to express the competitive pressure from other countries and is, of course, of high importance for an open economy like Germany. We assume that the consideration of imports and the concentration index, along with firm size, allow the identification of the degree of competitive pressure a firm is faced with.

The MIP covers companies that are active in Western and Eastern Germany (the former GDR). In the nineties, Eastern German companies received many tax incentives and direct subsidies from the government in order to support their development, so it is possible that Eastern German firms behaved differently from Western German ones with respect to innovation. Therefore, we include a dummy variable *EAST* that has unit value for companies operating in the Eastern German federal states.

It is possible that younger firms are also the more innovative ones, as the foundation of a firm usually goes hand in hand with the introduction of one or more innovations. The established firms may be reluctant to introduce "fundamental" innovations like those launched by newly founded companies. The new firms are possibly also those that enter new markets. In order to take account of the effect of the age of a company, we include the log of firm age (ln*AGE*).

Furthermore, we control for firm heterogeneity with respect to engagement in international trade. The share of sales exported, *EXPORT*, is measured on the individual firm level and describes its participation in international competition. Firms which decide to partipate in international trade, perhaps at the same time decide to invest into innovative activity in order to offer attractive products and to produce at competitive costs.

It is well known that the technical opportunities differ considerably between industries. We include 13 two-digit industry dummies in order to control for specific effects. The industry "food products and beverages" is the basis for the comparison. Furthermore, two time dummies indicate whether an observation is from 1993 or 1995. The year 1992 is the basis in this case.

Descriptive statistics of the variables are presented in Table 1. If we consider the full sample, we find that 36% of firms are categorized as incumbents by our definition. The proportion of potential entrants is about 5%. In the subsample of innovators, 65% are defined as incumbent firms, and 9% as challengers. Furthermore, we see that average license expenditures amount to 280,000 EUR in the subset of innovators, which is around 2% of firms' total innovation expenditures, on average. Finally, note that average firm size in the innovators' subsample is approximately 617 employees, while the average firm in the full sample employs around 421 people.

Table 1: Descriptive Statistics (3,559 observations)

Variable	Mean	Std. Dev.	Min.	Max.
Full sample, 3,559 observations				
LICENSE (in EUR million)	0.15	1.94	0	85.80
LICENSE / SALES * 100	0.07	0.38	0	7.68
LICENSE / TOTINNO	0.01	0.05	0	1
EMP	421.46	1,385.84	10	33,500.00
INCUMBENT	0.36	0.48	0	1
ENTRY	0.05	0.23	0	1
EAST	0.31	0.46	0	1
HHI	42.83	56.74	3.26	444.95
EXPORT	0.19	0.22	0	1
IMPORT	0.30	0.25	0.06	1.48
1/*AGE*	0.14	0.16	0.01	1
Sample of innovating firms, 1,915 observations				
LICENSE (in EUR million)	0.28	2.63	0	85.80
LICENSE / SALES * 100	0.12	0.51	0	7.68
LICENSE / TOTINNO	0.02	0.07	0	1
EMP	617.72	1,804.30	10	33,500.00
INCUMBENT	0.65	0.48	0	1
ENTRY	0.09	0.29	0	1
EAST	0.28	0.45	0	1
HHI	47.82	61.50	3.26	444.95
EXPORT	0.25	0.23	0	1
IMPORT	0.30	0.22	0.06	1.48
1/*AGE*	0.13	0.16	0.01	1

Note: 12 industry dummies and 2 time dummies not presented.

3.2 Estimation results

As already noted, not all firms have license expenditures - in fact it is a minority. Therefore, the dependent variable is censored and we have to apply Tobit regression to account for this. We start with homoscedastic Tobit models and test for heteroscedasticity afterwards.

Full Sample

It turns out that we find remarkably robust results for the three different specifications: incumbents have higher expenditures for licenses than the other firms (see Table 2). We explain this result by the strategic incentives of incumbents. To the best of our knowledge this is the first test on the Gilbert and Newbery (1982) model using data on licensing expenditures. Perhaps the most surprising result is the difference between R&D (cf. Czarnitzki and Kraft, 2004) and license expenditures. Incumbents and challengers behave in exactly the opposite way if R&D is compared with licensing, and this difference is in line with theoretical reasoning. In our view, this result can be explained by the absent uncertainty for license purchases, in contrast to R&D activities which are subject to inherent risk.

Table 2: Homoscedastic Tobit models using the full sample

Variable	ln(*LICENSE*)	ln(*LICENSE / SALES* * 100)	ln(*LICENSE / TOTINNO*)
INCUMBENT	3.97 ***	4.75 ***	3.27 ***
	(0.49)	(0.57)	(0.39)
ENTRY	1.12	1.29	0.90
	(0.82)	(0.95)	(0.65)
EAST	-2.54 ***	-2.87 ***	-2.06 ***
	(0.74)	(0.85)	(0.58)
ln*EMP*	2.15 ***	2.09 ***	1.38 ***
	(0.19)	(0.22)	(0.15)
HHI (t-1)	0.001	0.001	0.0004
	(0.004)	(0.005)	(0.004)
EXPORT	3.06 ***	3.52 ***	2.35 ***
	(1.03)	(1.20)	(0.82)
IMPORT (t-1)	-3.05	-3.36	-2.08
	(2.54)	(2.95)	(2.00)
1/*AGE*	0.25	0.51	0.53
	(1.71)	(2.00)	(1.35)
Intercept	-24.53 ***	-26.47 ***	-19.94 ***
	(2.68)	(3.12)	(2.12)
LR test on joint significance of 12 industry dummies	$LR(\chi^2(12))$ = 54.35***	$LR(\chi^2(12))$ = 51.94***	$LR(\chi^2(12))$ = 45.03***
LR test on joint significance of 2 time dummies	$LR(\chi^2(2))$ = 51.69***	$LR(\chi^2(2))$ = 49.49***	$LR(\chi^2(2))$ = 51.10***
# of obs.	3,559	3,559	3,559
Log-Likelihood	-1,954.79	-2,020.02	-1,873.73
McFadden R^2	0.14	0.12	0.13

Note: *** (**, *) indicate a significance level at 1% (5, 10%).

In addition to the homoscedastic Tobit models, we also computed heteroscedastic models, because coefficients estimated in the homoscedastic case are inconsistent in the presence of heteroscedasticity. Therefore, the variance σ in the likelihood function is simply replaced by

$$\sigma_i = \sigma \exp\left(\alpha ' z_i\right),$$

where α denotes the parameters of the heteroscedasticity term to be estimated, and z_i is the vector of variables included in the heteroscedasticity term. We consider the industry dummies, time dummies, six size class dummies (based on the number of employees), and *EAST* as variables potentially entering the heteroscedasticity term (multiplicative groupwise heteroscedasticity). This choice set is based on *LM* tests on the basis of the estimates under the assumption of homoscedasticity. Subsequently, we estimated the heteroscedastic model including all those variables and also models with restricted sets of variables potentially causing heteroscedasticity (see e.g. Greene, 2000: 912-914, for technical details on the tests). First, we find that in the models using ln(*LICENSE*) as dependent variable, the assumption of homoscedasticity is not rejected on the basis of *LR* tests. Therefore, we omit the heteroscedastic version for this case. Second, the *LR* statistics indicated that it is sufficient to include the six size dummies in the heteroscedasticity term. See Table 4 in the appendix for results of the heteroscedastic models. As a general conclusion, we find that although heteroscedasticity is present in the models using ln(*LICENSE / SALES* * 100) and ln(*LICENSE / TOTINNO*) as dependent variables, the interpretation of results remains robust and confirms the findings of the homoscedastic models presented above: incumbents show higher licensing expenditures.

Moreover, we find that Eastern German firms are less likely to purchase licenses than Western German firms. This could also be seen as further evidence on the behavior of incumbents and potential entrants. In the early 1990s, Eastern German firms, in general, may well be seen as challengers, because after the German re-unification in 1990, these firms were either newly founded or emerged from the large combinates of the former German Democratic Republic that had been split into several independently operating entities after re-unification. Thus, such firms were not established in the market, while West-German firms can be seen as incumbent firms. The break-down of the Eastern European markets – the foreign markets where GDR firms were operating in – at the same time further strenghtens the argumentation that Eastern German companies behaved as market challengers. If one agrees to this view, the negative coefficient of *EAST* again supports the theoretical prediction of the Gilbert-Newbery model, namely that incumbents invest more licenses. Interestingly, Czarnitzki and Kraft (2004) found exactly the opposite result when R&D is considered as dependent variable: there Eastern German firms, the challengers, showed a higher R&D intensity.

With respect to the other covariates, we find following evidence: As expected, the larger the company the more it spends on licenses. This is in line with the Schumpeter hypothesis that larger firms spend more on innovative projects. However, it also supports the hypothesis that larger firms prefer to reduce the risk of innovation by purchasing technology from other inventors. It is possible that they are not interested in radical innovations discovered by their own internal R&D activities, but favor incremental innovations to secure their market position. We also checked a non-(log)linear specification of firm size, and this did not change the results. Moreover, the firm age has no effect on license strategy.

The export variable is positively significant. We explain this result as follows: consider a company that decides to export intensively. In this case, it needs superior products and efficient production techniques. Both may, at least partly, realized by technology licensing agreements.

The Herfindahl index and imports measuring competitive pressure turn out to be insignificant. Since both the Herfindahl index and imports are measured at the industry level, they might not be able to capture the actual degree of competition accurately enough.[5] Of course, it may well be the case that heterogeneity in competition is already absorbed by the twelve industry dummies. We computed likelihood ratio (*LR*) tests on the joint significance of the twelve industry dummies (see Table 2), and the statistics indicate that the coefficients of the dummies are different from zero at the 1% level in all three regressions. The same applies to the two time dummies.

We also studied the effects of the industry dummies in closer detail referring to the key results of Anand and Kim (2000) for US licensing activity. They report that licensing activity in the US between 1990 and 1993 was most important in the Chemicals (especially drugs), Computers and Office Equipment, Electronic Components, Communications Equipment, and Surgical and Medical Instruments industries as defined by the SIC classification. Our German dataset covers the period from 1992 until 1995, and although the European standard industry classification

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[5] We study the effect of competition further in a sensitivity test below.

called NACE is not fully comparable to SIC, interesting similarities can be found: we derived marginal effects on the probability that an observation is not censored from the Tobit regressions (not presented in the regression tables), i.e. the probability that firms show positive license expenditures.[6] Analyzing the average marginal industry effects *ceteris paribus*, we find that the probability of license purchases is highest for "Medical, Precision and Optical Instruments, Watches and Clocks" (5.4%), "Telecommunications Equipment; Computers and Office Equipment" (5%), and "Chemicals (incl. drugs)" (4.7%). This is a surprisingly similar pattern in Germany and the US. Differences are that the average marginal effect of the "Electronic Components" industry, which shows high activity in the US, amounts only about 3% which is not a particularly high result in the German sample. Further, we find that the "Other Vehicles (includes, among others, aircraft, locomotives, ships, motorbikes)" shows a relatively high marginal effect of 4.8%, but that may be a small sample artefact, because there are only 61 observations in this group. In conclusion, we find very similar industry effects to those described by Anand and Khanna (2000) for the US in a similar period.

Subsamples

In a second step, we only consider the subsample of innovating firms (1,915 observations). The regressions show that the results are robust (cf. Table 3). The previous findings were thus not driven by non-innovators in the sample. The subsample of innovating firms describes a group of companies that shows at least some engagement in technological progress. Purchasing licenses is one innovation strategy among others, e.g. conducting one's own R&D activities. Again, we find that incumbents spend more on licenses in order to facilitate the innovation process than potential entrants. The other results persist as well, although the export variable is only significant at the 10% level in two of the three models.

Again, we tested for heteroscedasticity as described above, and find that the assumption of homoscedasticity is not rejected in the model for ln(*LICENSE*). The

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[6] The marginal effects presented refer to the model using ln(*LICENSE*) in Table 2. The other models yield similar conclusions.

heteroscedastic models for the other two equations are relegated to the appendix, as the interpretations of empirical findings did not change (cf. Table 5 in the appendix).

Table 3: Homoscedastic Tobit models using the subsample of innovators

Variable	ln(*LICENSE*)	ln(*LICENSE / SALES* * 100)	ln(*LICENSE / TOTINNO*)
INCUMBENT	0.97 **	1.12 **	0.77 **
	(0.48)	(0.56)	(0.38)
ENTRY	0.38	0.37	0.26
	(0.77)	(0.89)	(0.60)
EAST	-2.48 ***	-2.82 ***	-2.04 ***
	(0.74)	(0.85)	(0.57)
ln*EMP*	1.85 ***	1.63 ***	1.06 ***
	(0.19)	(0.22)	(0.15)
HHI (t-1)	-0.001	-0.001	-0.001
	(0.001)	(0.01)	(0.001)
EXPORT	2.10 **	2.34 *	1.52 *
	(1.05)	(1.21)	(0.83)
IMPORT (t-1)	-2.62	-2.73	-1.60
	(2.69)	(3.09)	(2.09)
1/*AGE*	-0.11	0.05	0.23
	(1.70)	(1.98)	(1.34)
Intercept	-24.37	-24.83	-17.90
	(1.95) ***	(2.25) ***	(1.48) ***
LR test on joint significance of 12 industry dummies	$LR(\chi^2(12))$ = 43.39***	$LR(\chi^2(12))$ = 41.17***	$LR(\chi^2(12))$ = 35.92***
LR test on joint significance of 2 time dummies	$LR(\chi^2(2))$ = 14.56***	$LR(\chi^2(2))$ = 13.83***	$LR(\chi^2(2))$ = 14.64***
# of obs.	1,915	1,915	1,915
Log-Likelihood	-1,860.67	-1,921.48	-1,773.67
McFadden R^2	0.07	0.05	0.05

Note: *** (**, *) indicate a significance level at 1% (5, 10%).

As a further check of the robustness of results, we also considered the subsample of Western German companies only. Although we argued that Eastern German companies may be seen as challengers and Western firms as incumbents, it is worthwile to check whether our main specification with respect to *INCUMBENT* and *ENTRY* is robust within the Western German sample. We ran the same regression models both on all Western German firms in the sample, and also on innovating Western German companies only. Again, it turned out that the previous results are persistent and the conclusions remain the same. Incumbents invest more in licenses than challengers. For this reason, the estimation results on the Western German sample are not presented in detail, but are available from the authors upon request.

Further robustness test with respect to competition controls

The conventional measure for competitive pressure is a concentration index like the Herfindahl index. The disadvantage of such measures is it, that international competition is neglected and the impact of potential entry is also not been accounted for. Therefore we use the Lerner index, i.e. the price-cost margin (*PCM*), in addition to the Herfindahl index. We compute the Lerner index as

$$PCM_{it} = \frac{\text{sales}_{it} - \text{personnel costs}_{it} - \text{material costs}_{it}}{\text{sales}_{it}}.$$

This empirical approximation of the Lerner index was proposed first by Collins and Preston (1969) and Ravenscraft (1983), and takes account of international and potential competition. Nickel (1996) and Nickel et al. (1997) use a related measure, namely firm rents, to measure competition. Okada (2004) uses averages of *PCM* to control for competition at the industry level. Based on a theoretical model, Boone (2000) states that any parameter increase that leads to an increase of the relative profit share of firms would be a suitable measure of product market competition.

The problem of using this variable in our empirical study is that of potential endogeneity, because licensing expenditures might increase profitability in the long run. However, due to the lack of reliable instruments, we are unable to work with IV estimations. We consider this as an additional test on the robustness of our results and find that our main results are not altered, if the Lerner index is included.

Table 6 displays the estimation results including *PCM* as a further variable controlling for competition including potential and international competitive pressure. We find that *PCM* is highly positively significant in all regressions. One could already interpret this result as evidence that increasing incumbency reflected by an increase in *PCM* has a positive effect on licensing expenditure. Moreover, our variable *INCUMBENT* is positively significant, and ceteris paribus it even raises license expenditures if a firm is defined as an incumbent. Consequently, we conclude that the predictions of the Gilbert-Newbery model are also supported in these modified regressions.

4 Conclusion

Licensing is the topic of numerous theoretical papers but very rarely, if at all, empirically tested. Based on a sample of German firms we perform an econometric test concerning the question of who spends more on licensing, the incumbent or the challenger. It turns out that the incumbents invest more in licenses than potential entrants. Hence, our results are in line with the Gilbert and Newbery model. This is, to the best of our knowledge, the first empirical test that explicitly considers bidding for inventions whose pay-offs are not subject to uncertainty; unlike R&D spending, for instance. Therefore, our empirical set-up is as close as possible to the auction model of Gilbert and Newbery, at least in a non-experimental framework.

A comparison between the results of our earlier study (Czarnitzki and Kraft, 2004) and the outcome of the test reported in this paper reveals how important the differentiation between R&D and other innovation activities is. Incumbents invest less in R&D but more in licenses. In light of the theoretical literature available, the differences with respect to risk and time seem to provide the explanation for these results.

The limitations of the theory are that the Gilbert and Newbery model does not discuss oligopolies with an unlimited number of potential entrants. Clearly this would be the most relevant case for an empirical test, because monopolistic markets hardly exist in reality. Of course, the empirical tests also have their limitations. As discussed in Section 3, theoretical work is usually based on the case of process innovation. With our data source, we principally would be able to identify *ex post* whether a firmcompany has realized a product or process innovation, but we have no information about the purpose of the license expenditures. Even more complicated would be a differentiation according to drastic and non-drastic innovation, which is highly relevant in the case of the auction model. Solving these problems is obviously an ambitious task for further research.

Furthermore behavioral reasons like inertia might also be relevant. For example, firms that have been in business for long time may become inflexible. Newcomers have more structural flexibility and are open to new ideas. If this description is true, established firms are perhaps forced to buy licenses, as they are not innovative enough. At least the radical innovations frequently come from newly founded companies or entrants, while the incumbents look more for incremental innovations. A possible observation of higher license expenditures might be the consequence of inertia by the incumbents instead of the strategic aspect emphasized by Gilbert and Newbery (1982) and others.

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Appendix

Table 4: Heteroscedastic Tobit models using the full sample

Variable	ln(*LICENSE / SALES* * 100)[a]	ln(*LICENSE / TOTINNO*) [a]
INCUMBENT	4.65 ***	3.16 ***
	(0.57)	(0.39)
ENTRY	0.82	0.63
	(0.98	(0.66)
EAST	-2.98 ***	-2.18 ***
	(0.90)	(0.61)
ln*EMP*	2.80 ***	1.92 ***
	(0.31)	(0.20)
HHI (t-1)	0.002	0.0008
	(0.005)	(0.004)
EXPORT	3.42 ***	2.24 ***
	(1.19)	(0.81)
IMPORT (t-1)	-3.56	-2.15
	(2.94)	(1.98)
1/*AGE*	-0.85	-0.30
	(2.06)	(1.36)
Intercept	-30.08 ***	-22.73 ***
	(3.34)	(2.24)
LR test on joint significance of 12 industry dummies	$LR(\chi^2(12))$ = 51.92***	$LR(\chi^2(12))$ = 47.11***
LR test on joint significance of 2 time dummies	$LR(\chi^2(2))$ = 47.58***	$LR(\chi^2(2))$ = 50.61***
# of obs.	3,559	3,559
Log-Likelihood	-2,007.23	-1,857.86

Note: Standard errors in parentheses. *** (**, *) indicate a significance level at 1% (5, 10%).
[a] Heteroscedasticity term includes six size class dummies (based on employment).

Table 5: Heteroscedastic Tobit models using the subsample of innovators

Variable	ln(*LICENSE / SALES* * 100)[a]	ln(*LICENSE / TOTINNO*)[b]
INCUMBENT	1.17 **	0.77 **
	(0.56)	(0.37)
ENTRY	0.02	-0.04
	(0.91)	(0.62)
EAST	-2.76 ***	-3.55 ***
	(0.89)	(1.23)
ln*EMP*	2.47 ***	1.56 ***
	(0.28)	(0.19)
HHI (t-1)	-0.001	-0.001
	(0.01)	(0.001)
EXPORT	2.50 **	1.52 **
	(1.18)	(0.78)
IMPORT (t-1)	-3.00	-1.12
	(3.04)	(2.04)
1/*AGE*	-1.56	-0.42
	(2.02)	(1.30)
Intercept	-24.30	-17.37
	(3.25) ***	(2.11) ***
LR test on joint significance of 12 industry dummies	$LR(\chi^2(12))$ = 45.38***	$LR(\chi^2(12))$ = 37.29***
LR test on joint significance of 2 time dummies	$LR(\chi^2(2))$ = 15.95***	$LR(\chi^2(2))$ = 9.88***
# of obs.	1,915	1,915
Log-Likelihood	-1,907.99	-1,745.93

Note: Standard errors in parentheses. *** (**, *) indicate a significance level at 1% (5, 10%).
The *LM* and *LR* test statistics on heteroscedasticity led to following specifications:
[a] Heteroscedasticity term includes six size class dummies (based on employment).
[b] Heteroscedasticity term includes six size class dummies, two time dummies, 12 industry dummies and *EAST*.

Table 6: Sensitivity Analysis: Tobit models including *PCM* (full sample)

Variable	ln(*LICENSE*)[a]	ln(*LICENSE / SALES* * 100) [b]	ln(*LICENSE / TOTINNO*) [b]
INCUMBENT	3.90 ***	4.56 ***	3.09 ***
	(0.49)	(0.57)	(0.39)
ENTRY	1.12	0.82	0.62
	(0.81)	(0.97)	(0.65)
EAST	-1.99 ***	-2.29 **	-1.70 ***
	(0.75)	(0.91)	(0.62)
ln*EMP*	2.18 ***	2.86 ***	1.97 ***
	(0.19)	(0.31)	(0.20)
EXPORT	3.23 ***	3.62 ***	2.38 ***
	(1.03)	(1.19)	(0.80)
IMPORT (t-1)	-2.84	-3.33	-2.00
	(2.52)	(2.92)	(1.96)
1/*AGE*	0.44	-0.67	-0.18
	(1.70)	(2.05)	(1.36)
HHI (t-1)	0.001	0.001	0.001
	(0.001)	(0.01)	(0.001)
PCM	4.63 ***	5.30 ***	3.72 ***
	(1.40)	(1.58)	(1.06)
Intercept	-32.40 ***	-39.39 ***	-28.47 ***
	(2.09)	(2.84)	(1.89)
LR test on joint significance of 12 industry dummies	$LR(\chi^2(12))$ = 50.87***	$LR(\chi^2(12))$ = 48.13***	$LR(\chi^2(12))$ = 42.50***
LR test on joint significance of 2 time dummies	$LR(\chi^2(2))$ = 50.49***	$LR(\chi^2(2))$ = 46.73***	$LR(\chi^2(2))$ = 49.76***
# of obs.	3,559	3,559	3,559
Log-Likelihood	-1,949.24	-2,001.57	-1,851.68

Note: Standard errors in parentheses. *** (**, *) indicate a significance level at 1% (5, 10%).
The *LM* and *LR* test statistics on heteroscedasticity led to following specifications:
[a] Homoscedastic model.
[b] Heteroscedasticity term includes six size class dummies (based on employment).