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Knowledge Diversity, Coherence and Out-licensing of Knowledge: An Innovation Process Perspective

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Abstract

During the last decades outward knowledge licensing (OKL) has become considerably important in business practice. In the biotech industry, OKL has evolved to a sustainable business model. Despite this development OKL has received less academic attention. This paper addresses an extensive research gap by analyzing the impact firm?s knowledge diversity and coherence on OKL from a dynamic innovation process perspective. Hypothesizes are developed by combining knowledge based view with the new product development framework and arguments form licensing literature. We employ a unique project based dataset from the pharmaceutical industry, comprising the innovation project portfolio of 280 pharmaceutical firms. Applying zero inflated negative regression models, our results suggest a positive relationship between knowledge diversity and OKL at the firm level as well as at the level of single innovation phases. For knowledge coherence a negative effect is proven also at the firm and the phase level.

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During the last decades outward knowledge licensing (OKL) has become considerably important in business practice. In the biotech industry, OKL has evolved to a sustainable business model. Despite this development OKL has received less academic attention. This paper addresses an extensive research gap by analyzing the impact firm's knowledge diversity and coherence on OKL from a dynamic innovation process perspective. Hypothesizes are developed by combining knowledge based view with the new product development framework and arguments form licensing literature. We employ a unique project based dataset from the pharmaceutical industry, comprising the innovation project portfolio of 280 pharmaceutical firms. Applying zero inflated negative regression models, our results suggest a positive relationship between knowledge diversity and OKL at the firm level as well as at the level of single innovation phases. For knowledge coherence a negative effect is proven, also at the firm and the phase level.

Keywords: Knowledge, diversity, coherence, licensing.

1. Introduction

Knowledge based view considers knowledge as the most important strategic resource. Access to superior knowledge enables firms to coordinate and recombine their resources and competencies in innovative ways, resulting in competitive advantage (Grant 1996). Even if a firm has less unique resources, superior knowledge enables firms to exploit and develop existing resources in a more advanced way than competitors. The ability of a firm to anticipate changes in the environment and to identify, acquire, transform, integrate, store, share and efficiently apply knowledge in order to encounter those dynamics is the most important capability for gaining sustainable competitive advantage (Kogut/Zander 1992, Spender/Grant 1996, Teece 2004, Eisenhardt/Martin 2002). Since knowledge is characterized by context specificity, complexity, embeddedness in organizational routines, tacitness and path dependency resulting in a high degree of causal ambiguity, knowledge tends to fulfill Barney's VRIO-criteria of sustainability in competitive advantage (Barney 1991,1997).

In this article, we concentrate on licensing as a mechanism to share internally generated knowledge across firm's boundaries. From the knowledge originator perspective, we address the apparent paradoxical issue of why and under which circumstances firms share their knowledge by out-licensing, in particular if this intellectual resource is from high strategic relevance.

Following the technology management literature, we refer outward knowledge licensing (OKL) to a contractual arrangement whereby the licensor sells the rights to use knowledge in form of patents, trademarks and manufacturing, marketing and technical expertise to the licensee. Licensee and licensor can be firms, organizations or individuals (Reepmeyer 2006). This article concentrates on firm-firm licensing agreements. Traditional technology management literature considers licensing as alternative to foreign direct investment in terms of technology transfer (Baranson 1970, Adam et al. 1988, Saggi 1999). On the firm level several studies on the licensing behavior of firms exist which analyze industry specific, firm specific or technology specific determinants of firm's willingness to out-license knowledge (Lichtenthaler 2007, Gambardella et al. 2007, Kim/Vonortas 2006). We go beyond these previous finding. In a first step, we combine arguments form the technology licensing literature with the knowledge based view to build a more general theoretical basis. On this basis, the relationship between firm's knowledge base and OKL is explored. We concentrate on two properties of the firm's knowledge base: knowledge diversity and coherence. In a subsequent step arguments from the new product development (NPD) process approach are included. OKL is referred to a repeated strategic decision which comes up several times during the new product development process. A dynamic perspective enables the identification of dynamics within the relationship between knowledge diversity, coherence and OKL during the new product development process.

2. Theory and hypothesis development

2.1. A knowledge based perspective on outward knowledge licensing

From knowledge based view, the increasing importance of OKL in business practice raises the fundamental question of why firms are willing to share their knowledge and which factors determine this decision, especially if knowledge is highly essential for economic success.[1] Sharing knowledge with licensees bears the risk of dimishing competitive advantage because the licensees get access to at least a fraction of the licensors unique and superior knowledge base.

In general, the knowledge base of every firm is affected by dynamic changes in the relevant environment. When managing these dynamics, firms may encounter situations in which they have to handle the tensions between exploiting existing knowledge and exploring new knowledge (He/Wong 2004). Implementing effective knowledge exploration and knowledge exploitation strategies requires at least some degree of inward and outward oriented openness of the firm's knowledge base (Lichtenthaler/Lichtenthaler 2009). Thus, the decision for or against OKL is can be associated with the firm's capability to manage the current and future knowledge base. Following this argumentation, OKL is driven by knowledge exploitation or knowledge exploration motives. Exploitative OKL motives are related to the objective of an efficient usage of existing knowledge in the short term (March 1991, Levinthal/March 1993). OKL is implemented as a mean to realize financial returns and cost savings, to commercialize knowledge which does not fit with the company's overall knowledge base, to share risks and cost of knowledge production and to ensure freedom to operate.[2] An important

[1] We exclude the special case of compulsory licensing since in that case the decision for or against out-licensing of knowledge lies outside the control of the licensee.
[2] Freedom to operate is ensured by a special type of cross-licensing agreement which should prevent the inventing company from legal proceedings regarding to patent infringements (Lichtenthaler 2007).

instrument of exploitative OKL is cross licensing. Such agreements facilitate the access to strategic relevant complementary knowledge and assets outside the firm. This is especially important when innovation is sequential or based on general purpose technologies (Gambardella et al. 2007). Furthermore, licensing to competitors can prevent them from building different standards or an own research focus within the same research field. Standard setting and technological leadership is facilitated by OKL which fosters effective knowledge exploitation in the future. Explorative OKL motives are aimed to ensure the future innovativeness of the firm and to manage conditions under which competitive advantage is realized in the long run. OKL is for example used to ensure access to complementary knowledge outside the firm which will become strategically relevant in the future, regardless if this knowledge already exists or will be generated the future (Lichtenthaler 2009). It is important to notice, that explorative and exploitative OKL motives are not strictly independent. Firms OKL behavior is driven by several knowledge exploitation and knowledge exploration motives and their interplay. For example, contemporary license relationships ensure external exploitation of firm's contemporary knowledge. At the same time, these relationships strengthen and extend firm's networks and ensure future accessibility to complementary strategic resources which are necessary for knowledge exploration in the long term.

Besides strategic motives, OKL is more fundamentally determined by characteristics of the underling knowledge itself. Teece (1986) shows that explicit knowledge is much more often transferred by licensing agreements than tacit knowledge due to superior transferability. Furthermore the protectability, generality, exclusivity and the value of the knowledge are crucial for the licensing out decision (Kim/Vonortas 2006; Gallini 2002).

In this paper, we go beyond previous findings concerning the drivers of firms OKL behavior. We carve out the diversity and coherence of firm's knowledge base as well as the development stage of the knowledge as further important determinants of OKL decision. To build on a reasonable theoretical foundation, we combine arguments form knowledge based view, technological licensing literature and the new product development approach.

2.2. Knowledge diversity, knowledge coherence and the decision to out-license knowledge

In order to analyze the relationship between firm's knowledge and OKL activities, we concentrate on two properties of the firm's knowledge base: the diversity and the coherence. Knowledge diversity comprises the diversity in knowledge systems and principles underlying the nature of products and their methods of production. Knowledge diversification is related to the process of the expansion of corporate knowledge base at the input side of the firm (Granstrand /Oskarsson, 1994). A certain degree of knowledge diversity is worthwhile to decrease the risk of being depended on only few knowledge domains. This is particularly relevant in highly volatile industry environments where considerable knowledge dynamics takes place. Knowledge diversity ensures sufficient levels of risk diversification and strategic options. In KBV literature it is well recognized that the diversity of firm's knowledge base is likely to influence the willingness and ability of a firm to integrate external knowledge (Cohen/Levinthal 1990, Jansen et al. 2005). More implicitly, there are some reasons why knowledge diversity should be expected to influence outward oriented knowledge flows and OKL strategies. In general, OKL requires at least some openness of the firms' knowledge base. Specialized firms which rely on a specialized knowledge base may pursue more restrictive knowledge outflows because of high competitive risks. A more diversified company might have stronger incentives to out-license internally generated knowledge for several reasons. First, knowledge which is located outside the core knowledge of a diversified firm can be licensed out to non-direct competitors who are not active in the same core knowledge domains. Risk and cost of the generation of non-priority, non-core knowledge can be shared without creating additional competition in core knowledge domains (Molas-Gallart 1997). The results of Gambardella et al. (2007) strengthen this argumentation. The authors give empirical evidence that firms tend to out-license peripheral knowledge more frequently and keep core-knowledge mainly in house in order to prevent additional direct competition and rent dissipation effects. But also in core knowledge domains, OKL could be a favorable option for a diversified firm for overcoming resource constraints. In general, increased levels of diversity are accompanied by higher requirements concerning the scare resources and competencies of the firm. If the innovation activities of a firm are spread over many diverse knowledge domains, resource constraints may become particularly crucial. Out-licensing of well selected knowledge opens then the possibility not to share costs and risks, but also resource requirements.

As already pointed out, OKL itself is neither costless nor riskless. But compared to specialized licensor, a diversified licensor has a higher potential to minimize the negative impact of OKL to direct competition and rent dissipation effects. Given this considerations, we propose the following hypotheses concerning the relationship between knowledge diversity and OKL behavior of firms:

Hypothesis 1: OKL depends positively on the diversity level of the firm's knowledge base. The higher the knowledge diversity the higher the scope of out-licensed knowledge.

Crucial when considering the relationship of firm's knowledge base and OKL behavior is furthermore the realized synergetic potential within the knowledge base. A knowledge base which is characterized by high synergies facilitates sophisticated knowledge spillovers. Those enhance efficiency and lower the need to access external knowledge or resources. If the resources and competencies required to push ahead different innovation projects are similar or even identical, they are more easily available and accessible within the firm. As a consequence the relevance of OKL as a mean to get access to external commentary resources can be expected to be lower for firms with high knowledge synergies than for firms with less synergies. Furthermore a high synergetic potential within the firms knowledge base can be assumed to indicate a strong concentration of research activities on very similar and related knowledge. Under such circumstances out-licensing of knowledge to external firms creates not only additional direct competition in the respective knowledge domains. Simultaneously, due to the synergic potential of the out-licensed knowledge, additional potential prospective competition is created within the related knowledge domains. This is especially hazardous within branches or technological fields which are characterized by high consolidation tendencies (Arora/Fosfuri 2003).

The level of synergies within the firm's knowledge base depends on the coherence level of the firm (Teece et al. 1994; Piscitello 2000, 2004; Valvano/Vannoni 2003). Coherence is achieved when the activities conducted by a firm rely on a common or complementary knowledge base, share common resources or use scientific principles and similar heuristics of search (Breschi et al. 2003). Given this considerations a negative relationship between knowledge coherence and OKL is expected.

Hypothesis 2: OKL depends negatively on the coherence level of the firm's knowledge base. The higher the knowledge coherence the lower the scope of out-licensed knowledge.

So far, our hypotheses refer to the static firm level. But in business practice, the decision about OKL is not a static, one-time strategic issue. It comes up several times during the innovation process. To deepen understanding of the relationship between knowledge diversity, coherence and OKL we extent the aforementioned arguments by a more dynamic intra-firm process perspective. Following the new product development (NPD) framework, the innovation process is considered as a knowledge generating process which can be broken down into subsequent stages (Utterback 1974; Utterback/Albernathy 1975). Each stage is characterized by a clearly defined activity set, an associated knowledge base as well as by stage specific risks, costs and strategic decision (Saren 1984). Within each stage additional knowledge and value is created. During NPD, feedback loops within and between the individual stages facilitate dynamic organizational learning (Pisano 1994, Spender 1996). The decision for or against out-licensing can be taken, confirmed or revised at every single stage of the NPD process. For example, a firm can decide to out-license internal knowledge only on a temporarily basis or only for the activities associated with a specific innovation stage.

The switch from a static firm-level perspective to an inter-phase comparison leads to a change in the extent of ceteris paribus assumption underling the general relationships proposed in H1 and H2. During NPD dynamic changes in the endogenous and exogenous knowledge environment takes place which may influence the intensity of diversity and coherence effects on OKL. For example, for a firm with a given diversity level, OKL might become more likely in innovation phases with considerable risks than in less risky phases in order to share risk and resource requirements. The changing phase specific risks and costs also influence in-licensing behavior of potential licensees. An unfavorable risk/cost-ratio let potential licensees become more defensively and restrained in entering new licensing-in agreements (Arnold et al. 2002, Fitzgerald 1992). High phase specific costs in combination with a high risk of knowledge devaluation and obsolescence may hamper the positive knowledge diversity effect on OKL. In a similar vein, the intensity of the relationship between coherence and OKL is assumed to be dependent on the innovation stage at which licensing out takes place. To strengthen the understanding of knowledge dynamics, we propose the following hypotheses concerning the relationship between knowledge diversity, knowledge coherence and out-licensing behavior of firms at different stages of the innovation process:

Hypothesis 3. The intensity of the relationship between knowledge diversity and OKL depends on the innovation stage where OKL takes place.

Hypothesis 4. The intensity of the relationship between knowledge coherence and OKL depends on the innovation stage where OKL takes place.

3. Data and Methods

In order to analyze diversification and coherence effects on OKL behavior of the firm, we concentrate on the pharmaceutical industry. An industry focus ensures identical external industry dynamics for all sample firms. Such a setting is especially meaningful for complexity reduction and validity within a process level comparison. Furthermore, the pharmaceutical industry provides a worthwhile framework for the research purpose of this paper. The pharmaceutical industry is associated with a high knowledge and innovation intensity where considerable knowledge dynamics takes place (Kandampully 2002). OKL becomes an increasingly widespread business practice of incumbent and startup firms (Findlay 2007, Festel et al. 2010). Furthermore, there is some empirical evidence, that OKL is carried out at every stage of the drug development process (Quinn 2000).

The innovation process in the pharmaceutical industry portrays new drug discovery and development as proceeding in a sequence of possibly overlapping, but clearly definable innovation phases. The realization of spillovers and economies of scope is crucial for successful drug development (Henderson/Cockburn 1994, 1996, Cockburn/Henderson 2001, Graves/Langowitz 1993). Additionally, a clear identification of research projects, associated research areas, licensing agreements and NPD history is possible due to the regulation of the food and drug administrations. Data was collected from the database Pipeline (Informa Healthcare). This database provides a comprehensive history of pharmaceutical R&D projects from 1980 until today. Research history of new drug development projects starting form preclinical testing up to market introduction are covered by manuals available on Pipeline. All significant new prescription drug candidates of all major pharmaceutical and biotech firms worldwide are included. At the end of 2011 the database was comprised of 33599 projects of 3936 innovating actors like public and private companies, universities and research institutes.

The data offered is based on information from national and international regulatory authorities, public trials registries, conferences, research institutes, journal and press releases, and from company communication. Such secondary data is particularly useable in a pharmaceutical context since this industry is characterized by high prevalent disclosure obligations and an extensively open communication of the latest discoveries and inventions via various channels (Henderson/Cockburn 1996, Scherer 2010). We completed the data received from project description manuals available in Pipeline with information gained by analysis of documents and information from regulation authorities and companies themselves. Financial data was obtained from the OSIRIS database, annual reports, official firm information and firm communications. All available process stage data available in Pipeline was included. This allows us to differentiate in analogy to Utterback (1971) between three stages of the NPD which distinguishes most in their underling activities and knowledge set. Stage 1, the idea generation phase, covers preclinical development which comprises screening and synthesis of new compounds and testing in assays and animal models. Stage 2 the problem solving phase, covers all activities of clinical human testing, which typically comprises three successive phases. In clinical phase I, usually a small number of healthy volunteers are tested with the compound to gather information about absorption, distribution, metabolic effects, excretion, toxicity, and dosage. A larger number of people suffering from the targeted disease are the participants of clinical phase II-trials to gather preliminary data on safety and efficacy. Clinical phase III-trials are conducted on a large number of subjects. Large-scale trials are aimed at evaluating optimum efficacy conditions and to identify rare side-effects. Stage 3, the implementation phase, comprises all activities concerning the registration of promising new drug candidates at national or international regulatory authorities as well as preparing marked introduction[3] (DiMasi et al. 2003).

Concerning the risks and cost of the individual phases in the pharmaceutical innovation process, several studies exist. Most popular are the studies of DiMasi and co-authors (DiMasi 2000, 2001, 2002; DiMasi et al. 1991, 2003). In general, the majority of the innovation costs incurred during the clinical trials (stage 2). The lowest phase specific costs are caused after the clinical trials before market launch (stage 3) (Paul et al. 2010). A common measure for phase specific risks is the attrition rate. The attrition rate is defined as the number of projects which enter phase p_t but fails prior to the subsequent phase p_{t+1}[4] relative to the total number of projects which enter phase p_t. There is a strong relationship between the attrition rate and the cost of individual phases. Attrition rates are highest for the clinical tests (stage 2) and lowest short before registration and market introduction (Stage 3). Phase specific costs and risks differ between therapeutic areas. But the general inequality: cost and risk of clinical testing > costs and risk of preclinical testing > costs and risks of pre-registration and marketing is the same for all therapeutic areas (Paul et al. 2010, Kola/Landis 2004).

The data set includes NPD phase specific information on projects within the active project portfolio of 280 private, international pharmaceutical companies at the end of 2011. In order to examine phase

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[3] We concentrate on the new product development process. Basic research is a preceding process and not part of the NPD. As a consequence, basic research activities are not subject to our study. An analog differentiation can be found in Henderson, 1994 and Henderson/Cockburn, 1996.

[4] $t \in \mathbb{N}_0$.

specific knowledge dynamics we selected only those firms which were conducting at least one innovation project at each of the three defined NPD-stages.

3.1 Dependent Variable

The dependent variable measures the firms OKL behavior. We select a measurement which considers the quantitative dimension of OKL. The dependent variable is the number of out-licensed innovation projects of a firm (LIC). The dependent variable is assessed at the firm level as well as on the level of individual NPD stages. It is important to note, that the number of out-licensed projects can also be interpreted as some measure of commercial success of the knowledge which is created by firm specific competencies and resources from the beginning of an innovation project until the time of out-licensing. The commercial value of the out-licensed knowledge is valued at the market for knowledge. But interpreting OKL as success indicator has to be done with caution. The special type of commercial success which is assessed by the fact of out-licensing is not generalizable to the overall marked success of an innovation. It is limited to knowledge which is offered by the originator at the market for knowledge (Teece 1998). Because of strategic reasons firms keep some knowledge inside. Since this knowledge is not offered at the marked for knowledge, no commercial value can be determined, even if the potential demand and value at the market of knowledge would be very high.

3.2 Technological Diversification

To measure knowledge diversity, the entropy measure is chosen. An application of the entropy measure for determining knowledge diversity requires the differentiation of clearly defined knowledge domains. The present study uses a therapeutic-oriented classification derived from the official classification of the European Pharmaceutical Market Research Association (EPhMRA). This classification differentiates between 14 distinctive therapeutic areas.[5] Therapeutic areas reflect anatomically oriented fields of research defined by specific pharmacological and chemical characteristics. All drug development projects are assigned to one or more therapeutic areas. The therapeutic area assignment was used to derive measures of diversification on the input side of the firm. Knowledge diversity is defined as the spread of the firm's drug development project portfolio over therapeutic areas. The entropy measure of diversity measure takes the breadth as well as the depth of the firm's knowledge base into account. Breadth is considered by the number of different therapeutic areas in which a company conducts projects, depth by the number of projects conducted within each individual therapeutic area. Formally, knowledge diversity is defined as follows:

$$DIV_f^s = \sum_{t=1}^{14} P_{ft}^s \log\left(\frac{1}{P_{ft}^s}\right)$$

[5] An overview of the 14 therapeutic areas is available at Table A1 in the Appendix.

Let P_{ft}^{s} denote the number of projects in NPD stage s, conducted in therapeutic area t within the firm f in relation to the overall number of projects conducted within the stage s in firm f (s = 1,2,3; t = 1,..,14). The entropy measure is limited by a lower bound of 0, the upper bound depends on the number of defined research areas. For 14 therapeutic areas the upper bound is at 1.146. Diversity is also calculated at the overall firm level, taking all active innovation projects into account, regardless to their associated NPD stage.[6]

3.3 Coherence

Coherence is measured by an index based on cosine similarity that was originally proposed by Engelsman and van Raan (1992) and modified by Breschi et al. (2003, 2004). Differentiating knowledge domains by therapeutic areas, each single project is dedicated to one or more therapeutic areas. The reason for a drug candidate assignment to several therapeutic areas is a multiple physiological effectiveness. For example, acetylsalicylic acid (also known as aspirin) is used to treat headaches but it can also be used for blood dilution. Formally, let $I_{tp}^{s} = 1$ if project p which is conducted in stage s, is relevant in therapeutic area t[7], otherwise $I_{tp}^{s} = 0$ The sum of projects relevant in therapeutic area t at stage s is therefore determined by $N_{t}^{s} = \sum_{p} I_{tp}^{s}$. In analogy we indicate the sum of phase s-projects relevant in both, therapeutic area t and u as $J_{tu}^{s} = \sum_{p} I_{tp}^{s}\, I_{up}^{s}$ which is a simple addition of joint-occurrence[5]. Applying J_{tu}^{s} to all stage s innovation projects under consideration for 14 therapeutic areas, this leads to a symmetric 14x14 matrix of joint-occurrences (**J$_s$**). Since **J$_s$** is symmetric[8], each column or each line of **J$_s$** constitutes a therapeutic area specific vector of joint-occurrence. Applying the cosine similarity, denoted as C, allows for calculating the similarity of vectors by their angular separation. Cosine similarity reaches its maximum for therapeutic areas with identical vectors. This is the case, when therapeutic area 1 shows the same structure as therapeutic area 2 regarding the mutual joint-occurrence with the remaining 12 areas. Cosine similarity C_{tu}^{s} is defined as the correlation between the vectors J_{tk}^{s} and J_{uk}^{s} divided by their euclidean distance and is therefore interpreted as a correlation coefficient.

$$C_{tu}^{s} = \frac{\sum_{k=1}^{14} J_{tk}^{s}\, J_{uk}^{s}}{\sqrt{\sum_{k=1}^{14} {J_{tk}^{s}}^{2}}\ x \sqrt{\sum_{k=1}^{14} {J_{uk}^{s}}^{2}}}$$

The cosine measure of similarity is calculated for each individual innovation stage s (s=1,2,3). A stage specific calculation allows us to take changes in the relatedness between distinctive therapeutic areas into account. As the activity set as well as the associated knowledge and competence requirements of individual innovation stages change with NPD progress, it can be expected that the synergetic

[6] Formally, the DIV-Formula is the same for the firm level, only the upper index "s", accounting for individual stages, has to be dropped.
[7] t = 1,…,14; u = 1,…,14.
[8] This is true since no differentiation between the included therapeutic areas associated with one specific project is made when calculating I_{tp}^{s}. Therefore $J_{tu}^{s} = J_{ut}^{s}$ is fulfilled.

potential of therapeutic areas differ to some extent between innovation stages. For the calculation of the cosine similarity all projects available in the Pipeline database are considered. The coherence level of the stage specific project portfolio of firm f is calculated in two subsequent steps. First, for every therapeutic class and stage, a weighted average of relatedness (WAR) is built, which represents a firm specific measure of the average relatedness in the knowledge base of the therapeutic area t and any therapeutic areas in which the firm f conducts at least one stage s-project. We denote O to be the complete number of all innovation projects conducted by all innovative pharmaceutical firms in a certain period of time within stage s. O_u^{fs} then comprises the number of phase s-projects conducted from firm f in therapeutic area u.

$$\text{WAR}_{fst} = \begin{cases} \dfrac{\sum_{t \neq u} C_{tu}^{s} O_u^{fs}}{\sum_{t \neq u} O_u^{f,s}} & if\ O_u^{fs} > 0 \\ 0 & otherwise \end{cases} .$$

The overall coherence of a firm's knowledge base in phase s is defined as the weighted average of the WAR_{fst} measures: $COH_{fs} = \frac{\sum_{t=1}^{14} O_t^{fs} * \text{WAR}_{fst}}{\sum_t O_t^{fs}}$. COH_{fs} equals 0 if there are no knowledge commonalities and complementarities in the phase specific knowledge base of firm f. COH_{fs} reaches its maximum of one for a fully coherent knowledge portfolio in phase s. COH is also calculated at the overall firm level, taking all active innovation projects into account, regardless to their associated NPD stage.[9]

3.4 Control Variables

The empirical model controls for other potential effects which are likely to influence the OKL-behavior of firms. First, we control for innovativeness of conducted projects since knowledge innovativeness is expected to positively influence knowledge valuation at the external market of knowledge. More innovative projects are assumed to be more demanded by potential licensing partners than less innovative projects. To control for innovativeness effects, we take the number of new chemical entity (NCE) - projects in relation to the number of all drug projects into account. A new chemical entity is a genuinely new drug with a new chemical structure which was not previously known. A NCE goes far beyond simple modifications or improvements of existing drugs concerning dosage, formula, or chemical structure. NCE's provide significant therapeutic advances and reflect the firm's R&D ability to deal with complex innovation processes and to create radical new knowledge and innovations (Cardinal 2001). The share of NCE-projects is calculated for every individual NPD phase. Furthermore a firm specific dummy is included to control for size effects. According to prior research, a smaller firm size is expected to be associated with a higher propensity to license out projects during the NPD process. Smaller firms may be forced to license knowledge to more lager incumbents to overcome strong resource constraints. Larger and well-resourced firms are more restrictive in OKL in order to avoid increased competition and rent dissipation effects (Motohashi,

[9] Formally, at the firm level, the index "s" within the C-, COH-, and WAR-formulas has to be dropped.

2008). However, in absolute terms as considered by the dependent variable of this study, larger firms are tend to out-license a higher absolute number of their projects, since the draw on a more comprehensive project portfolio. So a positive relationship between firm size and number of out-licensed projects is expected. We classify the size of the sample firms according to the scheme of the European Commission by sales into three categories. To account for year specific fluctuations we calculate the sales average of a three-year timespan (sales at observation year, sales one year before and one year after the observation year). For all firms, sales were converted into euros, based on the respective exchange rate at the end of every fiscal year of every firm. Table 1 summarizes the size distribution of the sample firms.

Table 1. Size distribution

Category	**Sales in mio. Euro**	**No. of sample firms**	**No. of firms/total**	**% of total licensed out R&D projects**
Small	≤ 10	118 (42,14%)	42,14	9,9
Medium	> 10 and ≤ 50	88 (31,43%)	31,43	26,9
Large	> 50	74 (26,43%)	26,43	63,2
Total		280	100	100

To take the possible bias form unobserved heterogeneity into consideration, a further variable is introduced. This variable reflects the past values of the depended variable. On the firm level, the number of completed projects (at the observation time) which were subject to OKL-agreements during their development (prior to the observation time) is taken into account. On the phase level, the number of projects which have already passed the phase under consideration (prior to the observation time) and had been out-licensed at this phase is considered, even if they are already introduced in the market.

3.5 Descriptive Statistics

Table 2 presents the descriptive statistics of the independent variables and the dependent variable. The mean of knowledge diversity is highest in stage 2 (0.42) and lowest for stage 3 (0.33). The average knowledge diversity in phase 1 is 0.34 and only slightly higher than in stage 3. The average coherence of the stage specific knowledge portfolio decreases with NPD progress. The mean of coherence is 0.39 for stage 1, 0.38 for stage 2, and 0.27 for stage 3. A comparison of phase 1 and phase 2 suggests a switch to a more exploitative research approach. The diversity level increases at its peak at the most risk and cost intensive stage 2. Simultaneously the coherence level decreases only marginally. Obviously, within phase 2 firms try to extend the scope of innovation projects to the maximum number of potential application fields. This can be achieved by through the generalizable and complementary character of the knowledge on which single innovation projects rely. With further progress of the innovation process, the diversity and coherence level decrease. Innovation activities and projects become re-focused on selected therapeutic areas. This specialization tendency is accompanied by a rather small level of coherence. The knowledge portfolio of a firm is most specialized in the NPD stage 3, short before market introduction. At the same time, the coherence is most limited in this stage. One explanation for this observation might be the high risk within phase 2 which leads to a cancellation of innovation activities in related, but peripheral knowledge domains. The dependent variable LIC passes its peak in stage 2 with an average value of 2.01 out-licensed projects. This emphasizes the high relevance of OKL as a mean for cost and risk sharing. In stage 1 the average value of LIC is 1.38. In this phase, time to market launch is longest and therefore the future value of the generated knowledge most uncertain. In stage 3, short before market launch, the average number of licensed out projects is 1.64 and therefore higher than in stage 1 and lower than in stage 2. On the firm level the average knowledge diversity is 0.56, the average coherence 0.57 and the average number of out-licensed innovation projects lies at 5.03. Comparisons of the firm level values with the stage specific value have to be carried out carefully. Firm level values comprise the accumulated number of projects which were also part of the disaggregated phase specific project portfolios. Therefore, a direct comparison between phase level and firm level descriptive values is less conducive. At least, it is important to notice that the standard deviation for knowledge diversity and coherence is less for firm level values than for phase specific values. This indicates a more stable degree of knowledge diversity and coherence between firms than within firms.

Table 2. Descriptive Statistics

Variable	**DIV**				**COH**				**LIC**				
Stage	1	2	3	f.l.	1	2	3	f.l.	1	2	3	f.l.	N
Description	knowledge diversity of phase s (s={1,2,3}) and at firm level (f.l.)				knowledge coherence of phase s (s={1,2,3}) and at firm level (f.l.)				number of licensed out projects in phase s (s={1,2,3}) and at firm level (f.l.)				
Mean	0.34	0.42	0.33	0.56	0.39	0.38	0.27	0.57	1.38	2.01	1.64	5.03	
S.D.	0.30	0.28	0.29	0.25	0.32	0.24	0.22	0.17	3.27	4.22	2.74	9.14	280
Min.	0	0	0	0	0	0	0	0	0	0	0	0	
Max.	0.97	0.99	1.01	1	0.90	0.87	0.79	0.89	23	32	18	66	

The coefficients of correlation between the variables of interest are presented in Table 3. A correlation table for the firm level variables is available in the appendix. A higher diversity of the firm's knowledge base can be associated with a higher level of coherence. This relationship holds true for all innovation stages. Furthermore, the level of diversity and coherence once realized in one NPD stage seems to influence subsequent NPD stages. From an empirical point of view, this indicates a coherent diversification pattern of firms during the NPD process. From a methodological point of view this observation should sensitize for the possible issue of endogeneity within a phase level analysis.

Table 3. Correlation Matrix

Correlations									
	DIV1	DIV2	DIV3	COH1	COH2	COH3	LIC1	LIC2	LIC3
DIV1	1								
DIV2	.559***	1							
DIV3	.521***	.55 3***	1						
COH1	.787***	.435***	.317***	1					
COH2	.242***	.661***	.245***	.298***	1				
COH3	.271***	.425***	.736***	.193***	.328***	1			
LIC1	.464***	.277***	.483***	.190***	.003	.191***	1		
LIC2	.462***	.324***	.478***	.213***	.039	.167***	.767***	1	
LIC3	.430***	.345***	.618***	.226***	.089	.271***	.610***	.663***	1

***. Correlation is significant at the 0.01 level.

4. Empirical Results

The dependent variable is the number of a firm's out-licensed projects (LIC). It is assessed on the company level as well as on the phase level for all three phases under consideration. For model selection we took three properties of the dependent variable into account. First, LIC is a count variable which adopts only nonnegative integer values. Second, LIC is characterized by overdispersion regardless of the considered level. Third, there are excessive zeros in the distribution of LIC. Therefore, a zero-inflated, negative binomial regression was employed. The idea behind a zero inflated model is that excess zeros being generated by a separate process from the count values. Excess zeros are modeled independently. In the research context of this paper this means that there are two processes that a firm can follow: OKL vs. no OKL. If the firm does not pursue OKL, the only outcome of this process is 0. Contrary, OKL is a count process. The expected count is expressed as a combination of the two processes.

Table 4 presents the estimation results of the relationship between number of out-licensed projects, knowledge diversity (DIV) and knowledge coherence (COH). The numbers in italics are the z-statistics. At the firm level, models are developed in columns 1-3. All three regressions include phase dummies to control for phase specific effects. The dummy d_phase2 is set to 1 for phase 2 values and to 0 otherwise. Accordingly, d_phase3 is set to 1 for phase 3 values, otherwise to 0. Phase 1 appears as base category. Furthermore, in all firm-level regressions we control for size effects (d_large for large firms, d_medium for medium firms, small firms=base category), innovativeness effects (NCE) and the prior values of the dependent variable (LIC_prior). We successively include the hypothesized main effects. In column (1) we estimate the contribution of knowledge diversity on the expected number of out-licensed projects. The coefficient is positive and significant. In column (2), we additionally estimate the effect of coherence on the expected number of out-licensed projects. The diversity effect remains positive and significant whilst the coefficient of coherence is significant as well, but negative.

This indicates a negative relationship between knowledge coherence and the dependent variable. In column (3) an interaction term of diversity and coherence is included. Diversity and coherence are two contemporary properties of the firm's knowledge base and are closely connected (Leten et al. 2007). The inclusion of an interaction term allows to test for a possible joint effect of knowledge diversity and coherence on the number of out-licensed projects. There is no evidence for a significant interaction effect. Furthermore, we find a negligible positive and significant effect of prior OKL-behavior on present number of out-licensed projects and no effect of innovativeness on the number of out-licensed projects. The results of the firm level regressions are supportive of Hypothesis 1 and Hypothesis 2. Firm level results indicate also that the innovation phase may matter when considering the determinants firms OKL-behavior. Initially, this is in line with our Hypotheses 3 and 4. To deepen the understanding of how diversity and coherence effects evolve with NPD progress, we run further phase level regressions. According to the firm level models, we run three regressions for every phase and include successively the main effect variables. In line with our full models, we find a significant positive relationship between diversity and the number of out-licensed projects in all regressions, regardless to the stage of the NPD. The significant negative coherence effect is also confirmed at the phase level as well as the significant and slightly positive effect of the number of prior out-licensed projects. Compared to the firm level we find two considerable differences in our stage level results. First, in contrary to the full firm level, there is a significant positive impact of knowledge innovativeness on the number of out-licensed projects in phase 1. Second, for phase 1 and phase 2 we find a significant influence of the joint effect of knowledge diversity and knowledge coherence on the dependent variable. Within phase 1, the coefficient of the interaction term is positive. After phase transition, the coefficient of the interaction term becomes negative for phase 2 and 1.5 as high in phase 1. In phase 3 there are no significant interaction effect.

The coefficients of a zero inflated negative binomial regression model have to be compared with caution. Coefficients in a non-linear regression are only indicators for the direction of an impact. In the linear regression model, the relevant slope coefficient equals the marginal effects. For non-linear models, this is no longer the case (Cameron/Trivedi 2005, p. 333). Marginal effects at means provide a good approximation of the amount of change in the dependent variable resulting from a 1-unit change in the independent variable, given average values of the independent variables.[10] Marginal effects at means are presented in table 5. The strongest impact of knowledge diversity on the number of out-licensed projects can be stated for stage 3 (2.765), the stage closest to market launch. The lowest impact of knowledge diversity on the number of out-licensed projects is realized in stage 2 (1.176). The marginal effects of knowledge diversity within phase 1 (1.287) and 2 are very close to each other. The marginal effect of phase 3 is 2.14 times higher than in phase 1 and 2.35 times higher than in phase 2. Furthermore, marginal effects reveal the highest negative impact of coherence on the number of out-licensed projects within phase 2 (-1.972), followed by stage 3 (-0.986) and stage 1 (-0.695). The

[10] Marginal effects at means are used.

negative marginal effect of phase 2 is two times as high as the marginal effect within phase 3 and 2.8 times as high as realized within phase 1. The marginal effect of the interaction term is 2.55 for phase 1. It becomes negative and 2.4 times as high in phase 2 (-6.01). In accordance with the raw coefficient, there is no significant marginal effect of the interaction term for phase 3. Under the prevailing model settings the econometric issue of endogeneity can arise for two reasons. First, because of reversed causality. This means that the estimated values of knowledge diversity and knowledge coherence may depend on the level out-licensed projects. To deal with this issue, we introduce the one-phase lagged values of diversity and coherence as instrument variables (Arellano/Honoré 2001). Second, there might be certain variability in the knowledge diversification and knowledge coherence level for the whole innovation process under consideration. If so, this leads to endogeniety problems in the consecutive values. To correct for this, the average level of firm's knowledge diversity and coherence is considered as variables.[11] These average values are independent from phases and constant for a firm. The estimated values for the lagged diversity and lagged coherence are both significant and have the same sign like the initial values, but they are slightly higher (see Appendix, table A3). These results validate the hypothesized positive relationship between knowledge diversity and OKL as well as the hypothesized negative relationship between knowledge coherence and OKL.

To strengthen our results with regard to the econometric issue of endogeniety, we additionally analyze the diversity and coherence effect for stable knowledge portfolios. This approach is based on the following intuitive idea: firms with approximately equal knowledge diversity (coherence) in all stages of the NPD are expected not to be subject to reverse causality. Obviously for these firms there is no positive or negative reverse effect of the dependent variable on knowledge diversity and coherence. If the estimated effect of knowledge diversity (knowledge coherence) on the number of out-licensed projects has the same sign and is significant for the subsample of stable diversified (coherent) firms, the proposed relationship between the dependent and independent variables can be assumed to be causal, given a sufficiently reduced endogeneity problem. Stable diversified (coherent) firms are defined by 10 percent of the maximum standard deviation of diversity (coherence), which leads to a maximum standard deviation of 0.114 (0.1) within the three innovation phases under consideration. 80 firms fall into the category of stable knowledge diversity, 67 firms into the category of stable knowledge coherence. Results of the subsample regressions support a causal positive impact of knowledge diversity as well as a causal negative impact of knowledge coherence on the number of out-licensed projects. Results are presented in Table A.4 of the Appendix.

[11]Regarding to the limited time frame, we use instrument-variable approach instead of panel data techniques.

Table 4. Binomial negative estimation of the number of licensed-out projects - coefficients

Dependent Variable	**Number of licensed-out projects – firm level**											
Level	firm level			phase 1 level			phase 2 level			phase 3 level		
	(1)	(2)	(3)	(4.1)	(4.2)	(4.3)	(5.1)	(5.2)	(5.3)	(6.1)	(6.2)	(6.3)
DIV	1.198***	1.801***	1.822***	1.312***	2.503***	2.202***	0.695*	1.174***	1.138***	2.385***	2.829***	2.851***
	5.76	6.58	6.61	3.63	5.35	4.45	2.07	2.76	2.78	7.93	7.67	7.69
COH		-1.019***	-1.088***		-1.718***	-1.188**		-0.905*	-1.906***		-0.979**	-1.017**
		3.36	-3.32		-3.52	-.19		-1.80	-3.46		-2.06	-2.09
DIVxCOH			-0.585			4.363**			-6.683***			-0.600
			-0.55			2.38			-3.82			-0.37
NCE	0.145	0.124	0.121	0.541**	0.615***	0.597***	-0.111	-0.178	-0.232	-0.215	-0.218	-0.219
	1.12	0.97	0.94	2.36	2.87	2.83	-0.54	-0.86	-1.15	-1.14	-1.16	-1.17
LIC_prior	0.004***	0.003***	0.003***	0.003***	0.002***	0.002***	0.005***	0.005***	0.004***	0.002***	0.001***	0.001***
	9.29	8.31	8.32	4.30	3.54	3.77	6.86	6.46	6.04	3.07	2.59	2.58
d_phase2	0.522***	0.481***	0.449***	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	4.57	4.26	3.54									
d_phase3	-0.225*	-0.270**	-0.291**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	-1.71	-2.07	-2.14									
d_large	1.085***	1.102***	1.099***	1.278***	1.430***	1.434***	1.328***	1.3328***	1.312**	0.642***	0.622***	0.618***
	7.13	7.26	7.24	4.41	4.94	4.95	5.70	5.74	5.80	3.21	3.10	3.08
d_medium	0.926***	0.926***	0.921***	1.091***	1.158***	1.201***	1.116***	1.098***	1.075***	0.515***	0.526***	0.520***
	6.71	6.73	6.69	4.02	4.28	4.44	5.34	5.74	5.26	2.81	2.87	2.83
Constant	-1.224***	-1.180***	-1.127***	-1.323***	-1.330***	-1.742***	-1.081***	-0.753***	-0.445**	-0.397***	-0.373**	-0.346**
	-8.83	-8.62	-6.71	-5.11	-5.40	-5.65	-5.46	-4.38	-2.42	-2,.76	-2.60	-2.14
Log likelihood	-1,066.12	-1,060.42	-1,060.27	-334.36	-328.16	-325.26	-424.42	-422.81	-415.56	-388.70	-386.55	-386.48
Sample firms	280	280	280	280	280	280	280	280	280	280	280	280
Share zero obs.	0.5607	0.5607	0.5607	0.6107	0.6107	0.6107	0.4821	0.4821	0.4821	0.45	0.45	0.45
LR chi2	435.82	447.22	447.52	141.39	153.78	159.58	160.58	163.81	178.30	186.90	191.21	191.34

z-statistics in italics; d_large: dummy variable, 1 if firm is categorized as large firm, 0 otherwise. d_medium: dummy variable, 1 if firm is categorized as medium, 0 otherwise. d_phase1 (d_phase2): phase dummy for firm level regression, 1 if phase 1 (phase 2) is considered, 0 otherwise . * Denotes significance at the 10% level, ** Denotes significance at the 5% level, *** Denotes significance at the 1% level.

Table 5. Marginal effects of full phase level models

Dependent Variable	**Number of licensed-out projects**		
phase level	phase 1	phase 2	phase 3
DIV	1.287***	1.176***	2.765***
	4.27	2.78	7.55
COH	-0.695**	-1.972***	-0.986**
	-2.18	-3.43	-2.06
DIVxCOH	2.552**	-6.012***	-0.582
	2.38	-3.85	-0.37
NCE	0.349***	-0.241	-0.212
	2.79	-1.14	-1.17
LIC_prior	0.001***	0.004***	0.001***
	3.49	5.44	2.52

z-statistics in italics; all regressions include size dummies
* Denotes significance at the 10% level.
** Denotes significance at the 5% level.
*** Denotes significance at the 1% level.

5. Discussion and Conclusion

This study examines the impact of knowledge diversity and coherence on OKL at the firm level and at different stages of the new product development process. Our main findings point out that NPD progress matters when determining the relationship between firm’s knowledge base and OKL. In a first step, we provide empirical evidence for a causal and positive relationship between knowledge diversity and the number of out-licensed projects. Furthermore, we find a causal and negative relationship between knowledge coherence and the number of out-licensed projects. This is supportive of our Hypothesis 1 and 2. We give empirical evidence for these relationships also at the level of single NPD stages. At the phase level, a general dynamic pattern in firms OKL practice is observed. The share of zero observations decreases with NPD progress. The portion of firms which out-license knowledge increases with NPD progress. A detailed phase specific analysis of the marginal effects reveals phase specific commonalities and differences as hypothesized in Hypothesis 3 and 4. The impact of knowledge diversity on the number of out-licensed projects is the lowest in stage 2. One possible explanation could be the unfavorable cost/risk-ratio of the clinical trials. These may lead to a limited demand for phase 2-projects on the side of potential licensees. Despite the less intensive diversity effect, it is important to notice that diversity seems nonetheless a very meaningful characteristic of firm’s knowledge within phase 2. Compared to the other NPD stages, stage 2 is characterized by the highest average of knowledge diversification and the lowest standard deviation in diversity. A diversified knowledge portfolio in phase 2 is obviously used to ensure risk diversification and to provide sufficient potential for various strategic actions at phase 2 and subsequent phases. Knowledge diversity is most relevant for out-licensing projects in phase 3, the phase with the most favorable cost/risk-ratio and closest to market launch. This is in line with our aforementioned licensee-oriented argumentation. Results are supportive of our Hypothesis 3. As realized at the firm level, knowledge coherence has also a consistently negative impact on the number of out-licensed projects at the level of every individual phases of the innovation process. The highest negative marginal effect of coherence on commercial innovations success is empirically proven for stage 2, the weakest negative effect is stated for phase 1. Relatedness in the project portfolio of pharmaceutical firms seems to hamper OKL. This becomes especially evident in the risk- and cost intensive phase 2. Drawing on more general previous findings in the literature, an explanation of this observation can be built on the following considerations. Commonly, a high level of coherence implies a strong and efficient research focus resulting from learning effects, shared resources, improved communication and coordination and greater internal knowledge spillovers between projects. Several studies give empirical prove that because of these properties, coherence fosters innovation and economic performance (Nesta/Saviotti 2005,2006; Leten et al. 2007). Given this relationship, coherence can be assumed as especially important at risky and costly innovation stages in order to ensure efficiency. This argumentation is in line with our descriptive phase-level findings (see table 2). On the other side, out-licensing parts of a coherent knowledge portfolio in risk- intensive phases is accompanied by partial or full transfer of knowledge which is highly relevant for future competitive advantage. At very risky innovation stages the future success of different knowledge types is highly uncertain for the firm. OKL at this stage bears the risk of transmitting unwittingly the most promising knowledge. As a consequence the inventor may become dependent in the future on knowledge which had been shared or which has to be shared with direct competitors. Additionally to the limited demand of potential licensees OKL may become a particularly treacherous strategic trap for coherent inventors in innovation phases with an unfavorable cost/risk-ratio.

Furthermore we find evidence for an interaction effect between knowledge diversity and knowledge coherence for the phases 1 and 2, indicating a dependence of the intensity of the diversity effect on the realized coherence level within these phases. In phase 3 no interaction is proven. The marginal effect of the interaction term in phase 1 is highly significant and negative. The diversification effect in phase 1 decreases with higher levels of coherence. Obviously, at higher levels of coherence, an increase in knowledge diversity let firms become more restrictive in OKL. Given the assessment of Garcia-Vega (2006) that knowledge diversity can act as entry barrier for potential innovators, our results indicate that at the beginning of the innovation process an increase of knowledge diversity at high levels of coherence let firms prevent potential entrants from entering the relevant knowledge domains by in-licensing. For phase 2 the marginal effect of the interaction term is highly significant as well, but positive. Contrary to phase 1, the diversity effect in phase 2 increases with higher levels of coherence. This result highlights again the particular importance of risk- and cost-sharing in phase 2. Only for phase 1 we find a significant innovativeness effect. Firms with a higher share of new chemical entities in their phase 1-project portfolio tend to out-license a higher number of phase 1-projects. Obviously, in phase 1, where the future outcome and market value of inventive knowledge is most uncertain, licensees bet on radical new external knowledge instead of external knowledge with incremental character. The potential future innovativeness premium in combination with a still considerable low degree of competition seems to give potential licensees an incentive to in-license radical new knowledge even at phase 1, where knowledge outcome is still highly uncertain. For all phases, past OKL-behavior of a firm influences positively contemporary OKL-behavior. The more projects a firm has been out-licensed in the past the more projects the firm out-licenses at present. Although this effect is highly significant and important to mention, the realized impact level is neglectable.

Concluding on our work from an academic point of view, we contribute to an extensive research gap. We address the relevance of knowledge diversity and coherence for firm's OKL by taking an eclectic theoretical framework into consideration. We combine arguments from the knowledge based view, licensing literature and new from new product development literature. Prior firm-level studies on licensing concentrate on the licensee's perspective or lack a comprehensive theoretical foundation. Furthermore, the few previous studies on OKL focus on the static firm level, neglecting the analysis of changes in knowledge base and knowledge characteristics during the innovation process. We explicitly consider OKL as a repeated decision which comes up several times during the innovation process. We give empirical prove that the relationship between knowledge diversity, coherence and the number of out-licensed projects is dynamic in nature. The intensity of the relationship depends on the progress of the innovation process and the underling knoweldge. This empirical observation goes far beyond prior research and establishes an important starting point for further firm- and phase- level research. From a methodological perspective we draw on a unique dataset and innovative project-based measures of knowledge diversity and knowledge coherence. Compared to traditional indicators like patents, project data is available at the phase level and not subject to time lags and firm-level or industry-level bias, for example caused by strategic behaviors of firms or industries (Pavitt 1985, Griliches 1998). Our findings are also relevant for managerial practice. The results point out the relevance of knowledge dynamics during the innovation process as an important determinant of OKL strategies. Diversity and coherence are not received automatically. They have to be considered during the whole NPD process and increased or decreased actively. Concrete measures may be to foster the awareness and exploitation of multiple physiological effects covered by an individual drug candidate as well as a prospective program and project portfolio management, which takes synergies and knowledge spillovers sufficiently into account. Besides the implications for technological and project management, the results are particularly useful for organizational design choices which aim to realize the full potential diversity and coherence effects.

Despite our essential contribution, our work is not free of limitations. To determinate the OKL behavior of firms we concentrate on a quantitative dependent variable, the number of out-licensed projects. For subsequent studies it might be interesting to evaluate OKL behavior by taking the quality dimension of the out-licensed projects into account. Furthermore, no differentiation of different licensee-licensor relationship-types is made. As discussed during the hypothesis development, the relationship type between licensee and licensor is likely to affect OKL-strategies. From a competitive perspective, OKL to non-direct and small licensors decreases the potential competitive risks caused by increased competition. Taking the size relation between licensee and licensor into account, Gans and Stern (2000, 2003) give empirical evidence that research-oriented, specialized start-up firm often earn their profits through licensing arrangements with more established, incumbent firms. This suggests a possible influence of the size, specialization but also of the licensee's integration level on licensors OKL behavior (Kollmer/Dowling 2004). Both, the consideration of size relation and the competitive relationship between licensee and licensor as determinants of OKL-strategies might be meaningful directions for further research. Furthermore, or results are gained within the industry specific context of the pharmaceutical industry. Teece (1998) points out, that this industry is characterized by particularly superior conditions for licensing activities. Compared to most other industries, the market for knowledge assets works highly efficient. On the one side, this makes validates your results, on the other side our results are limited in their reproducibility within a different industry setting. Due to a significant research gap, our study is explorative in nature. To deepen the understanding of the rationale behind the identified relationships, a subsequent qualitative empirical study is meaningful. For qualitative research, the combination of different literature streams, especially the knowledge based view and the NPD literature offers a fruitful framework for further process level investigations.

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Appendix:

Table A1. Differentiated therapeutic areas variables

No. Therapeutic Area	Therapeutic Area
1	Alimentary-metabolic
2	Blood and clotting
3	Cancer
4	Cardiovascular
5	Dermatological
6	Genitourinary
7	Hormonal
8	Immunological
9	Infectious Disease
10	Musculoskeletal
11	Neurological
12	Parasitic
13	Respiratory
14	Sensory

Table A.2 Correlation of firm-level

Firm level correlations

	DIV	COH	LIC
DIV	1		
COH	,723**	1	
LIC	,401**	,144***	1

***. Correlation is significant at the 0.01 level.

Table A3. Zero inflated regression model – main effects– endogenity considered.

Dependent Variable	Number of licensed-out projects				
phase level	1	2	3	1	2
$DIV_{average}$	4.428***	3.974***	3.629***		
	8.38	7.96	8.00		
$COH_{average}$	-4.676***	-3.106***	-1.759***		
	-5.63	-4.45	-2.83		
$DIVp\_{lagged}$				2.872***	3.312***
				5.29	6.96
$COHp\_{lagged}$				-3.963***	-2.933***
				-5.41	-4.74
NCE	0.795***	-0.099	-0.026	0.877***	0.048
	3.62	-0.46	-0.12	3.57	0.21
Constant	-1.207***	-0.899***	-1.029***	-1.492***	-0.618***
	-2.93	-4.01	-5.04	-5.73	-3.37
Log likelihood	-333.34	-430.14	-409.15	-344.53	-435.58
LR chi2	143.42	149.14	146.01	121.01	138.26

z-statistics in italics; all regressions include size dummies and control for unobserved heterogeneity.
* Denotes significance at the 10% level.
** Denotes significance at the 5% level.
*** Denotes significance at the 1% level.

Table A4. Regressions for firms with stable diversity/ coherence levels

Dependent Variable	**Number of out-licensed projects**			
Firm level	(i)	(ii)	(iii)	(iv)
DIV	1.511***	1.518***	1.605***	1.687***
	2.73	2.73	2.69	2.60
COH	-2.027***	-2.021***	-1.789**	-1.844**
	-3.13	-3.12	-2.25	-2.29
DIVxCOH		-0.411		-0.777
		-0.22		-0.34
NCE	0.054	0.058	0.182	0.183
	0.26	0.28	0.68	0.69
LIC_prior	0.003***	0.003***	0.003***	0.003***
	7.15	6.88	4.60	4.62
d_large	1.664***	1.653***	1.564***	1.550***
	5.36	5.28	4.83	4.76
d_medium	1.628***	1.621***	1.406***	1.340***
	6.04	5.98	4.98	4.98
d_phase2	0.146	0.121	-0.020	-0.053
	0.85	0.59	-0.09	-0.23
d_phase3	-0.891***	-0.908***	-0.710**	-0.743***
	-4.23	-4.05	-2.51	-2.49
Constant	-0.924***	-0.881***	-0.816***	-0.733***
	-4.01	-4.05	-2.75	-1.94
No. of firms	80	80	67	67
Share of zero obs.	0.521	0.521	0.567	0.567
Log likelihood	-322.51	-322.49	-262.07	-262.01
LR chi2	182.42	182.46	128.74	128.86

z-statistics in italics; all regressions include size dummies. * Denotes significance at the 10% level, ** Denotes significance at the 5% level, *** Denotes significance at the 1% level. Regressions in column (i) and (ii) for firms with stable knowledge diversity during the different NPD stages ($SD_{diversity} \leq$ 10% of maximum $SD_{diversity}$). Regressions in column (iii) and (iv) for firms with stable knowledge coherence during the different NPD stages ($SD_{coherence} \leq$ 10% of maximum $SD_{coherence}$).