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Motives to Publish, to Patent and to Standardize: An Explorative Study Based on Individual Engineers' Assessments

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ABSTRACT

This paper employs the concept of 'Gold' (financial rewards), 'Ribbon' (reputational/career rewards) and 'Puzzle' (intrinsic satisfaction) to structure engineers' motivation for pursuing scientific publications, patenting and contributing to standardization. This study is based on the responses to a survey of engineers employed by two German Original Equipment Manufacturers (OEMs) active in the automotive sector. Based on three explorative factor analyses, we identify in the first step factors of motives related to publishing, patenting and standardization. In the second step, we assign these factors to the three categories 'Gold', 'Ribbon' and 'Puzzle'. We find that the engineers surveyed assign a lower overall importance to career rewards and reputation and a higher importance to intrinsic satisfaction, while financial rewards are of lower importance, in general, and not at all relevant for contributions to standardization. In comparing these motivations with the drivers for researchers in public research organizations, we identify the role of regulatory framework conditions and intra-organizational structures in particular for researchers' intrinsic motivations. Finally, we derive some implications for companies', but also public research organizations' incentives and support schemes focusing on researchers.

1. Introduction

There are many different ways for companies and employees to deal with inventions. On the one hand, there are informal appropriation strategies (Hall et al. 2014), like secrecy (Arundel 2001), but also the disclosure of research results (Alexy et al. 2013) and on the other hand, proprietary instruments, such as patents, which are used to protect technological know-how. Arora et al. (2018) observe for a sample of R&D active companies traded in the United States a decline of companies' scientific publications in the last decades up until 2006. However, the number of patents they were filing remained relatively stable in contrast to the growth of patent applications at the global level (Fink et al. 2016). Camerani et al. (2018) report a slight increase in scientific publications between 2011 and 2015 for a worldwide sample of companies. In contrast, Baron and Spulber (2018) reveal a significant increase in the release of standards in the last decades, which can be perceived as a form of collaborative publication authored by companies and other stakeholders, due to an increasing need for interoperability, but also to position the own technology nationally, but preferably internationally. Overall, we perceive different trends regarding companies' scientific publishing, patenting and standardization activities.

Patents enable the acquiring and selling of technological know-how, whereas publications and standardization activities allow for strategic sourcing and revealing of knowledge related to innovation. Although patents, publications, and standards have a rather ambivalent relationship with each other, they are strategic instruments for the transfer of technology and the commercialization of R&D results (Zi & Blind, 2015, Blind et al. 2018). They can be used as research inputs, selective knowledge disclosure, codification and finally for the appropriation of research efforts.

Nonetheless, R&D employees are initiating inventions and pursuing scientific publications, patent applications or standardization activities and, therefore, contribute to their employers' *innovation* performance in a central way. However, only individuals' drivers for patenting and scientific publications have explicitly been considered both in practice and scientific investigations (see Perkmann et al., 2013) with only a few exceptions for standardization (e.g. Blind & Gauch 2009, Zi & Blind, 2015 and Blind et al. 2018) meanwhile also considered in the update of

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the review by Perkmann et al. (2021).

In contrast to universities with their strong emphasis on basic research, the industry relies on an incentive and support system in line with its economic purpose to motivate scientists and engineers for the application of their research results in practice. Whereas universities and public-funded research organizations offer their scientists a high level of freedom to pursue research, which attracts in general intrinsically motivated researchers (Lounsbury et al., 2012), the industry can offer higher salaries and career options.

Lam (2011) addressed for the first time the relationship between individual researchers' motivations and the increasing entrepreneurial orientation of universities and other research organizations. She links three concepts, namely, 'Gold' (financial) rewards, 'Ribbon' (reputational/career) rewards, and 'Puzzle' (intrinsic satisfaction) rewards, to different institutional settings. Recently, Suominen et al. (2021) have replicated Lam's approach in the context of research and technology organizations but found some important differences. Their researchers are mainly motivated by the exploitation of their research results and less by advances in academic research. Following Lam's work, Iorio et al. (2017) but also Suominen et al. (2021) reveal a fourth driver, the "mission" motivation, which has a positive effect on the variety and intensity of researchers' knowledge transfer activities. In the same direction goes 'moral' as the fourth category of drivers by Van de Burgwal et al. (2019), which are important for the performance in the civil society and governmental domains.

In contrast to numerous studies on companies' strategies, investigations about motivations of researchers active in the industry are quite limited and mainly focused on patenting. However, Sauermann and Cohen (2010) show that researchers' and engineers' motives, i.e. the desire for an intellectual challenge, income or responsibility, matter for their - and eventually for their companies' - innovative performance, measured by patents. Recently, Sauermann (2018) revealed the role of a weaker concern for job security in explaining higher innovative performance in start-ups. The role of individual innovators for companies' performance is supported by Mollick, (2012). However, Sauermann and Cohen (2010) do consider neither scientific publications nor the involvement in standardization as further strategies or measures of innovative performance. Furthermore, they do not differentiate between specific motives for patenting but only address the general drivers such as an intellectual challenge or for income and reputation.

We try to close these gaps about researchers' motivation in the industry by expanding the focus to publishing and standardization and by differentiating their motives related specifically to publishing, patenting and standardization. In structuring the motivations, we still apply the framework developed by Lam (2011) for academic researchers, applied by Suominen et al. (2021) also for researchers in more applied research and technology organizations to the publishing, patenting and standardization activities of engineers active in a research-intensive industry.

Based on our two-dimensional framework, we analyze and compare the motives of employees for publishing, patenting and standardization participation in the global automotive industry at two German 'Original Equipment Manufacturers' (OEM A and OEM B). We consider the automotive sector as an interesting research environment, because it shows a high R&D intensity. Despite some automotive industry companies still not being fully aware of the multidimensional value of patents, the automotive industry as such is quite active in patenting (Cohen et al., 2000; Großmann et al., 2016; Ili et al., 2010). Furthermore, the automotive industry has a long tradition in (transnational) formal and industrial standardization.

To tackle the lack of empirical evidence on in industry employed researchers` motivations for patents, publications and standardization, we conducted two surveys among engineers employed at both OEMs in 2014 and 2015. Due to a very similar database, we are able to match the survey results to generate a sufficient number of observations. The conducted factor analyses reveal various sets of motives related to the three types of activities, which will allow us to answer our research questions.

Finally, the publishing, patenting and standardization activities of engineers have important implications on technological change. First, scientific publications contribute to the public available knowledge pool being the base for technological change and eventually also economic growth. Second, patenting activities are also disclosing knowledge, but restrict its use to their owners and possible licensees. Therefore, they contribute also to technological change, but even more to companies' own economic performance (e.g. Andries and Faems 2013) and not necessarily to economies' growth, as shown by Blind et al. (2021). Finally, standards are, in general, like scientific publications, public goods driving technological trajectories in particular by contributing to dominant designs (e.g. Suarez 2004). Participation in standardization improves companies' economic performance, as well as standards contribute to long-run economic growth (Blind et al. 2021). Furthermore, companies participate in standardization not only to source knowledge exchanged within technical committees, but in Europe also to influence the implementation of technical regulations, which are often driven by protecting health, safety and the environment (Blind and Mangelsdorf 2016). In summary, the three activities and the motivations behind them have slightly different impacts on the speed of technological change. In addition, the contribution of scientific publications, patents and standards to the UN Sustainable Development Goals (SDGs) has been discussed since their publication in 2016. Whereas the highest number of scientific publications are dedicated to SDG 3 "Good Health and Well-being" followed by SDG 7 "Affordable and Clean Energy" (RELX Group SDG Resource Center 2020), the World Intellectual Property Organization WIPO perceives the focus of patents on SDG 9 "Industry, Innovation and Infrastructure" (https://www.wipo.int/sdgs/en/story.html) as well as the International Organization for Standardization ISO (https://www.iso.org/sdgs.html), which links in addition around half of their standards to the other 16 SDGs. Consequently, the individual motivations of researchers to follow the three activities have eventually also implications on the direction of technological change, like on the possible achievement of the SDGs, i.e. whether mainly commercial interests are in the focus or also social and environmental objectives are considered.

Our paper makes the following contributions. Whereas at the organizational level in general and company level in particular, the motivations to publish, patent and, standardize have been analyzed, we provide complementary insights about the motivations of individual engineers employed by two research-intensive companies. Therefore, they complement the findings based on the assessments of researchers in a publicly financed research institute. Finally, our findings allow us to derive several managerial implications also related to the contributions of the three strategies towards the SDGs.

The paper is structured as follows. The next section provides a review of the literature related to motivations for publishing, patenting and standardization activities, followed by the derivation of the research questions. The second section presents the characteristics of the analyzed companies. We then present the data and methods and the descriptive statistics of the survey. This part is followed by the exploratory factor analyses and the discussion of the factors in the context of 'Gold', 'Ribbon' and 'Puzzle' contributions, which is also answering our research questions. Finally, we discuss the results, elaborate our contribution to the literature and the managerial implications of our findings and eventually conclude with proposals for future research.

1.1. Literature Review

Before we differentiate between the motives of the three activities, i.e. publishing, patenting and standardizing, we start with the research on motivations of professionals in the industry in general. Kornhauser (1962) was amongst the first to deal with this topic. He assumes that the employees in the industry are interested in getting the rules of their professions into the organization's rewards and incentives schemes. However, he also admits that organizational and professional incentives may be incompatible, which makes a consistent incentive system difficult. In detail, he refers to Reissman (1949), who distinguishes between functional bureaucrats similar to the specialists introduced by Marvick (1954) and the cosmopolitans named by Gouldner (1957) driven by the reputation from a professional group outside of the organization they are working for. The professional bureaucrat is seeking recognition within the organization but not among professional communities, such as is the case with the institutionalist defined by Marvick (1954), the careerist by Wilensky (1956) or the local by Gouldner (1957) focusing on careers within the organization they are employed. The specialist bureaucrat is still following his professional orientation, but he seeks recognition from the department and the other employees he works with. Finally, the service bureaucrat is following personal goals related to non-professional groups in the context of his employment, such as with the hybrids defined by Marvick (1956) or politicos and missionaries by Wilensky (1956). Finally, Kornhauser (1962) argues and presents empirical evidence that depending on their orientation, employees seek to perform the most appropriate functions within an enterprise, which is also positive for their productivity. In general, companies face the dilemma of seeking too much the integration of their professionals and thereby losing their professional worth versus granting them too much autonomy and thereby, weakening their contribution to the organization. However, Perry et al. (2016) reveal that researchers' innovation orientation in hybrid, research-focused organizations is positively associated with both their organizational and professional commitment showing that they may not necessarily be incompatible.

Since companies in the automotive industry are heavily investing in research and development, they are also research-focused organizations, in which the tension between organizational and professional commitment for researchers and engineers is much lower than in the environment Kornhauser (1962) investigated. We still acknowledge that the level of autonomy for researchers in academia is much higher than those working by industry, which is bounded by the strategic direction determined by the management. This also explains the wage differences between industry and academia (Stern 2004). Nevertheless, the other framework conditions for scientists in public research organizations and engineers in firms are not so significantly different, which allows us to apply the framework developed by Lam (2011).

The literature on the activities and especially the performance of researchers active in public research organizations and universities has been strongly focused on scientific publications (e. g. Stephan, 1996). Recently, the publication activities of companies have also attracted the attention of researchers (e.g. the empirical overview of activities of German companies by Krieger et al. 2021). Simeth and Raffo (2013) investigate firms' motivations to disclose research outcomes in a scientific format. They consider both internal reasons and external aspects, such as knowledge sourcing from academic institutions. Their analysis reveals that firms are more likely to publish in academic journals if they need access to scientific knowledge. However, this is also often dependent on the level of knowledge spillovers in a sector and the effectiveness of legal appropriation instruments. In a follow-up study, Simeth and Lhuillery (2015) focus on the specific capabilities needed to enable firms to publish in academic journals. They provide evidence that scientific publishing requires specific human resources and support the view that scientific publications are not necessarily a by-product of conventional R&D activities. Notwithstanding, Simeth and Cincera (2016) confirm the net benefit of accessing academic information networks via scientific publications and its contribution to the company's patent portfolios despite the threat of unintended knowledge spillovers. Indeed, the additional effectiveness of scientific publications as a strategic means for firms to prevent others from patenting closely related inventions is also found by Della Malva and Hussinger (2012). Combining these insights, it becomes clear that companies benefit from being actively involved in scientific publishing. However, the existing studies do not reveal individual researchers' motivations for being involved in the timely and risky process of scientific publications.

Unlike the requirements and impact of companies being active in scientific publishing, the investigations of companies' patenting activities (e. g. Mansfield, 1986), strategies and their impact have a well-established tradition. In contrast to the missing insights into companies' motivations related to scientific publishing, companies' motives to patent have been investigated intensively (Arundel, 1995; Blind et al., 2006; Duguet & Kabla, 1998; Cohen et al., 2002). In addition to the traditional protection motive, patents are – like scientific publications – also used to block competitors patenting activities (Torrisi et al., 2016) as well as for commercial activities in general. Furthermore, patents can promote a company's reputation and image as well as facilitate access to capital markets and cross-licensing in the interaction with external stakeholders or also as an internal performance indicator. However, the relevance of the various motives depends strongly on companies' environment, i.e. sector, and characteristics, e. g. size. Consequently, patents' impact on a company's performance depends on various contingency factors (Hall et al., 2005). Nevertheless, the R&D engineers are the initiators of an invention and consequently of a possible patent application and therefore contribute significantly to the patenting performance of their employers, i.e. the companies. Therefore, it is also necessary to consider their motivations for patenting.

Unfortunately, the literature on the motivations driving an individual inventor to patent is quite limited. An exception is a study by Veer and Jell (2012), which focuses on individual inventors, who are disconnected from an organizational context and therefore are motivated by similar objectives as companies. Recently, Potekhina and Blind (2020) explored the patenting motives of Chinese inventors.

Furthermore, Giuri et al. (2007) surveyed the motives of more than 9,000 European individual inventors from several fields of technologies and from large to small- to mid-sized companies, public and private research institutes, universities, and other organizations. Their findings show the superiority of personal and social rewards over financial or career rewards, whereby the motive to contribute to the performance of the institution the inventor belongs to is rated most important, followed by personal satisfaction.

The motivation to patent by researchers active in publicly-funded research organizations has been addressed by Baldini et al. (2007), Baldini (2011), Figueiredo Moutinho et al. (2007), Hussler and Pénin (2012), Owen-Smith and Powell (2001) and Blind et al. (2018). However, only Mathew and Chakraborty (2012) look at the aims connected with patenting of Indian R&D engineers employed by IT and pharmaceutical companies. They identify wealth and fame as extrinsic, problem-solving orientation as intrinsic and contributing to society's knowledge as a somewhat extrinsic but altruistic motivation.

Scientists' patenting behaviour within universities and public research organizations often depends on their willingness to disclose their inventions (Bercovitz & Feldman, 2008; Figueiredo Moutinho et al., 2007; Siegel et al., (2003); Thursby et al., 2001). Owen-Smith & Powell (2001) argue in particular, that the scientists' propensity to patent depends on their perceptions of the expected benefits and barriers. The latter probably offsetting the former, leading to no involvement in patenting. However, Figueiredo Moutinho et al. (2007) find for Portuguese researchers that only expected tangible and intangible outcomes, i.e. financial rewards, reputation and career advancement, have a moderate impact on their patenting behaviour. The other motivations of patenting as an instrument for knowledge protection and dissemination, on the one hand and as a driver for the scope and pursuit of research strategies on the other hand have no impact on the actual patenting activities. Baldini et al. (2007) reveal four patenting motives based on a factor analysis of scientists at Italian universities. Besides supporting future research by primarily raising research funds, patenting promotes knowledge exchange as well as personal, tangible financial and intangible benefits due to visibility and reputation, which are perceived to be most important. Diametrical to the previous categories, Hussler and Pénin (2012) differentiate between proactive positive and reactive motives, which are driven by external factors. Overall, the various types of motives can be divided into intrinsic and extrinsic motivations.

Participation in standardization processes leads to the common development of standards.[1] Further, it represents an opportunity to source external knowledge from other participants. It is an option to commercialize one's own research results or technology directly by referencing one's own publications or patents in standards and indirectly by using standardization as an opportunity to establish collaborations with other companies or research organizations. In contrast to the considerable and increasing number of studies about scientists' patenting behaviour, e.g. reviewed by Perkmann et al. (2013), the participation of individual researchers in standardization has not been researched as much. Exceptions are the studies by Blind and Gauch (2009), Zi and Blind (2015) and Blind et al. (2018), who find academic superiority and the bias to applied research as positive and heavy engagement in basic research as a negative driver. However, there are some studies about companies' engagement in standardization (Blind, 2006; Blind & Thumm, 2004; Blind & Mangelsdorf, 2013; Wakke et al., 2015). Knowledge sourcing is identified by Blind and Mangelsdorf (2016) as companies' main motive to get involved in standardization in addition to influencing regulation, facilitating market access, pursuing company-specific interests and finding common technological solutions. Blind and Gauch (2009) investigate researchers' motivations related to standardization in nanotechnology. Researchers employed by companies rate the generation of legal security via standardization, e. g. by reducing risks of liability, preventing market dominance of proprietary standards and certain specifications to be integrated into standards as priority motives. In contrast, scientists of public research organizations have stronger priorities in shaping the specifications of standards and addressing particular technical problems meanwhile supported by Blind et al. (2018).

1.2 Derivation of Research Questions

Based on the 'self-determination' theory (Deci & Ryan, 2000; Ryan & Deci, 2000; Gagné and Deci, 2005), Lam (2011) and Sauermann and Cohen (2010) distinguish between intrinsic and extrinsic motives. Lam (2011) assumes that an individual's motive to behave in a certain way and their response to specific types of rewards depends on the degree of congruence between their personal values and those necessary for performing the responding activities. Consequently, researchers can be extrinsically or intrinsically motivated on different levels in performing an activity, depending on the internalization of the related values. The self-determination theory distinguishes in this context intrinsically motivated - from externally influenced - behaviour. According to Sauermann and Cohen (2010), individual researchers' motivation to perform an activity depends upon the expected benefits from engaging in that activity as well as upon the intensity of their preferences for these benefits (e. g., material vs immaterial). They perceive incentives as benefits that are contingent upon individuals' effort or performance and motives to individuals' preferences for such benefits. In contrast to Lam (2011), Sauermann and Cohen (2010) define extrinsic motivation as trying to gain benefits provided by some organizations active in the researchers' environment, e. g. superiors, peers or even the market, based on the assessment of effort or performance. They highlight that extrinsic benefits (e. g. financial remunerations) are not the immediate, but rather the indirect outcomes of performing research. In contrast, intrinsic motivation is driven by benefits originated by the individual researcher or the research activity itself crucially depending on the very specific interaction of the individual's and the activity's characteristics, irrespective of the external environment. However, researchers have also the desire to benefit others and society. This 'pro-social' motivation is a specific form of intrinsic motivation (Grant, 2008). Finally, intrinsic motivation depends on the autonomy of the researcher in choosing tasks and approaches, which might differ between industry and academic, but to a lesser extent in research-intensive industries.

Based on the available conceptual and empirical literature, we derive three generic questions regarding the general relevance of publishing, patenting and standardization for achieving 'Puzzle', 'Ribbon' or 'Gold' by researchers active in the industry taking the insights by Blind et al. (2018) focusing on scientists active in a public-funded research institute as reference.

Academic researchers' main objective is to "establish priority of discovery" (Lam, 2011, based on Merton, 1957 and Merton, 1973), by being the first to disclose a progress in knowledge, which is rewarded by the recognition of the relevant scientific community. This is known as the 'Ribbon'. The recognition of their peers based on accepted publications, their citations or awarded prizes is the basis of extrinsic rewards in academia. From these, extrinsic forms of rewards, like promotions and higher salaries, can be derived. However, publishing also enables researchers in firms to maintain links with the academic communities (e. g. Furukawa & Goto, 2006), but also to gain reputation and prestige in these communities (e.g. Stern, 2004), whereas those not disclosing their new insights in publications might be marginalized (McMillan et al., 1995).

However, academic scientists are also driven by solving challenging 'Puzzles', which might also have 'pro-social' impacts (Grant 2008), like contributions to the Sustainable Development Goals. From an economic perspective, researchers also behave like economic agents and are therefore interested in personal income, i.e. the 'Gold' (Levin & Stephan, 1991; Stephan, 1996). Firms can use publications to monitor their researchers' performance to link them with researchers' promotions or financial rewards (Cockburn and Henderson, 1998; Kinney et al., 2004; Li et al., 2015), as confirmed by Liu and Stuart (2014) in the biopharmaceutical industry. In contrast, Stern (2004) postulate that "scientists pay to be scientists", because firms with a science orientation pay lower wages to postdoctoral biologists. Complementary, firms pay higher wages for science and engineering PhD candidates, when they restrict researchers in publishing the results of their work (Sauermann and Roach 2014).

Within this multi-dimensional reward system, the 'Ribbon' is still the most crucial element not only because researchers are driven by the recognition received by their scientific community, but also due to its influence on researchers' resources and, as a consequence, researchers' salaries and access to future research funding. Analog to Lam's (2011) empirical results based on the assessment of academic researchers, we expect that also scientific publishing by researchers in firms driven by 'Ribbon', but probably also by 'Gold' depending on companies' financial incentive schemes (Camerani et al. 2018) with 'Puzzle' as base motivation. However, we derive the first general research question related to scientific publishing:

RQ1: What is the relevance of 'Puzzle', 'Ribbon' and 'Gold' as motives for researchers in the industry to publish?

In contrast to Baldini et al. (2007), Baldini (2011) and D'Este and Perkmann, (2011), who confirm the relevance of patenting both for 'Ribbon' and 'Puzzle' despite the theoretical option to raise significant

[1] According to EU-Regulation No 1025/2012 a standard is a technical specification, adopted by a recognized standardization body for repeated or continuous application, with which compliance is not compulsory. CEN, the European Committee for Standardization, publishes the following definition: "A standard is a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something. Standards are created by bringing together all interested parties such as manufacturers, consumers and regulators of a particular material, product, process or service. All parties benefit from standardization through increased product safety and quality as well as lower transaction costs and prices." According to ISO/IEC Guide 2.2004 standardization is an "activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context".

income via patenting, industry researchers are expected to emphasize its contribution especially to 'Gold' as already revealed by Matthew and Chakraborty (2012). In addition, analyses of inventors' compensations according to the German Employees' Inventions Act (Giummo 2014) reveal significant income streams, but only for very few inventors. Despite the likely focus on 'Gold', patenting is also connected to inventors' reputation. Therefore, we postulate no specific ranking of the motives, but just ask this very generic second research question:

RQ2: What is the relevance of 'Puzzle', 'Ribbon' and 'Gold' as motives for researchers in industry to patent?

Finally, despite the limited empirical evidence about industry researchers' motives for their engagement in standardization, we expect a possible relevance of standardization for 'Ribbon' due to the options of including own scientific publications in the reference lists of standards Blind et al., 2019. However, standards as outputs of standardization activities have no explicit list of authors. In contrast to publishing, standardization might have relevance for 'Gold', because of the stronger commercial motives of industry researchers via standard-essential patents, in particular in the area of information and communication technology (Kang & Motohashi, 2015). However, researchers involved in standardization might be intrinsically motivated by shaping specific standards, which might solve problems not only for the industry, but also the society as such, which should contribute to 'Puzzle' like revealed by Blind et al. (2018) for scientists in a public research organization. Therefore, we derive again a generic third research question related to standardization:

RQ3: What is the relevance of 'Puzzle', 'Ribbon' and 'Gold' as motives for researchers in industry to get involved in standardization?

Answering these three questions allows considering the relevance of motivations revealed by Blind et al. (2018) in a public-funded research institute as a reference to eventually provide answers to the fourth question, whether researchers' organizational type, i.e. private company vs public institute, influence their motives on publishing, patenting and standardization differentiated into 'Puzzle', 'Ribbon' and 'Gold'.

2. Characteristics of the Investigated Companies

The investigated OEM A and OEM B have their headquarters in Germany and dedicated departments for Intellectual Property (such as patents, licenses, and trademarks) and standardization. OEM A is a producer of premium cars and trucks sold globally under different brands with headquarters in Germany. The main strategies of OEM A are to produce the best products in their field of competition and to find new, customer-oriented mobility solutions that fully exploit the increasing digitalization. OEM B produces automobiles and motorcycles under a variety of brands with a broad product portfolio. The main strategies of OEM B are to use intelligent technologies to develop innovative solutions to become the leading automotive company. We chose these OEMs as they both aim to develop new, high-quality products but differ in their product portfolios. Finally, we had the possibility to survey a sample of their engineers. Unfortunately, both the selection of the sample and the survey design was not completely identical due to requirements set by the management of the two OEMs.

Prior to our employee surveys, we collected data from different internal (interviews and databases) and external sources during 2013 at OEM A and during 2015 at OEM B. The two companies are leading car manufacturers with global operations and headquarters in Germany. OEM A and OEM B have a variety of automotive business fields and brands but show some differences in their product portfolios. However, both OEMs have a high R&D intensity and focus on developing high quality and innovative products. Consequently, both companies are among the top ten of German patent applicants in recent years at the German Patent and Trademark Office (DPMA).

Yet, both OEMs give significance to supranational standardization activities in formal standardization organizations, like International Standardization Organization (ISO), and consortia, like AUTomotive Open System Architecture (AUTOSAR), to foster technological progress. Besides, OEM A aims 'to set the standard' in the market by enforcing their in-house developments. OEM B is also very active in standardization in order to set standards as well as to reduce license fees for standard-essential patents by taking part in many different standardization organizations and bringing in their own company-specific standards to work together on standards. Due to its modular platform strategy, OEM A also has a high focus on company standardization. Interestingly, participation in standardization becomes a pivotal instrument for innovation management of German OEMs (Großmann et al., 2016). The standardization strategies are neither directly tied to the corporate (innovation) strategies nor to the Intellectual Properties (IP) strategies. The employees taking part in standardization committees due to managerial decisions are mainly self-responsible, but they are supported partly by central standardization departments. Compared to the large number of patent applicants of 40.13 % of total R&D personnel at OEM A and 22.93 % at OEM B, the proportion of participants in standardization is very low. At OEM A, it is at 1.96 % and at OEM B at 1.4 % of total R&D personnel, respectively.

The role of publishing R&D results within the automotive industry seems to be a black box. None of the OEMs considered in our case studies provide an integrated intellectual property strategy for publishing and patenting (and standardization) and, furthermore, no central coordination authority. However, because the companies conduct basic and applied research and employ many highly-educated staff members, including PhDs, we can assume that they publish research results, which is supported by several hundreds of publications collected in the Web of Science, including links to the OEMs in the authors' addresses. Moreover, it may be assumed that OEMs utilize publishing for defensive disclosure (of inventions) based on participation at conferences and consortia or publishing research results of industry-academic co-operations. For both OEMs, a corresponding corporate directive gives guidance for the disclosure and (defensive) publishing of research results, and a dedicated review process for external publications exists.

Only in theory, an employee of a 'German OEM' can contribute voluntarily to inventions and file patents, publish as well as participate in standardization. In the case of patents, the employee invention remuneration system is based on the German Employees' Inventions Act (Giummo 2010). In contrast, the OEMs are not offering a direct financial remuneration for authors of scientific publications (unless agreed in the individuals' performance agreements) or standardization participants, who disclose or transfer their inventions into publications or standards. However, both OEMs honour outstanding standardization engagements of individual employees through special events.

3. Methodology and Data

In order to collect empirical data about the motivations for publishing, patenting and standardizing within the industrial realm and on the individual's level, we followed the survey research approach of Blind et al. (2018). To gather data, surveys at two OEMs in 2014 and 2015 were conducted. The difference is grounded in the fact that after completing the patent analysis and the survey in OEM A, OEM B was willing to conduct a similar, although not identical, approach.

Therefore, the survey was constructed after the consultation of literature. The researcher specific characteristics analyzed by Zi and Blind (2015) as well as the company level items for participation in the standardization of Blind and Mangelsdorf (2016) are transferred to the specifics of the automotive sector and - where possible - to the individual level. We pooled the data of the OEMs for our analyses since the two-tail Wilcoxon signed-rank test of the motives in the three fields of activity confirms that there is no significant (significance level of $p < .05$) difference between the responses of the engineers of both OEMs.

Via exploratory factor analyses, we condense and then rank the number of motivational items. Furthermore, the extracted motivational

Table 1
Distribution of employee activities of the OEMs (via aggregated surveys)

Group	Activity	Obs.	rel. (%)	rel. (%) Group A	rel. (%) Group B	rel. (%) Group C
A	Patent	844	75.49			
B	Publication	417	37.30			
C	Standardization	195	17.44			
A+B	Patent and Publication	360	32.20	42.65	86.33	
A+C	Patent and Standardization	133	11.90	15.76		68.21
B+C	Publication and Standardization	121	10.82		29.02	62.05
A+B+C	Patent and Publication and Standardization	90	8.05	10.66	21.58	46.15

Table 2
Ranking and exploratory factor analysis of publishing motives.

Motives to publish	Rank	Obs.	Mean (SD)	F1	F2	F3
Increase reputation of the employee	4	343	3.54 (0.99)	0.63		
Part of the individual performance agreement	11	333	1.52 (0.96)	0.66		
Scientific publishing promotes the professional career	9	316	2.86 (1.16)	0.70		
Are used as an internal performance indicator	10	340	2.39 (1.15)	0.86		
Increase reputation of the company	2	352	4.13 (0.82)		0.60	
Carry forward the state of art in science and technology via reviews	1	352	4.16 (0.80)		0.80	
Are effective for dissemination of scientific knowledge	3	346	3.97 (0.84)		0.83	
To demonstrate the superiority of own technologies when competing or substitutable technologies are present	6	339	3.48 (1.01)			0.65
Reviews of scientific publications (from third parties) carry forward the state of art in science	5	356	3.51 (1.15)			0.79
Result from participation in conferences, workshops, research projects and consortia	7	341	3.03 (1.24)			-0.50
Assessment of patentability via corporate publication approve process	8	350	2.92 (1.20)			

Notes: Ranking: The mean is the average on a 5-point Likert scale: answers between 1 (totally disagree) to 5 (totally agree).
SD = standard deviation.
Factor analysis method: principal-component factors with orthogonal varimax rotation. Obs.: 277. Kaiser-Meyer-Olkin measures overall 0.71. Explained variance: 0.57. Loadings between -0.5 and 0.5 are not displayed.

factors are applied to our conceptual framework of intrinsic and extrinsic motivations to contribute to patenting, publishing and standardization to confirm our propositions derived from the literature review.

We collected the data for the identification of the target groups of the surveys according to the following approach. First, data on employees' invention disclosures and patent applications for 2008-2013 for OEM A and 2003-2014 for OEM B were gathered. The OEMs made available a dataset on its employees' activities in formal standardization committees that are related to the German standards developing organization (DIN) for the respective periods. These employees participate in agreement with the employer in standardization, or they are assigned to participate by their employer to participate. An initial search to scientific publications of OEM A for the 2008-2013 periods was done by querying the bibliographic database 'Scopus'. We counter-checked the results by querying Thomson Reuters' 'Web of Science' database. Furthermore, we checked the consistency of the employees' data and clarified which of the identified authors were still employed at OEM A. For OEM B, the database of Thomson Reuters' 'Web of Science' was used, checking the consistency of the employees' data. The data were clarified by identifying the authors still employed at OEM B. As a result, we identified 5,680 employees of OEM A in total, including 12.25 % publishers and 4.65 % employees active in standardization committees. In the case of OEM B, about 2,345 employees were identified. For OEM B, the final sample composes 2,345 employees, including 7.38 % publishing employees and 6.14 % employees active in standardization. 91.6 % of the employees filed at least one patent.

In the second phase of our analysis, we gathered empirical data by conducting an anonymous and voluntarily online employee survey in March 2014 amongst 2,000 employees at OEM A whose activities for the period from 2008 through 2013 had been reported in our sample database. In September 2015, we surveyed 3,136 employees of OEM B who were active in either of the activities pertaining to our research.

To survey a representative sample of employees with expertise, we selected employees for our questionnaire at OEM A and OEM B with one or more scientific publications (PUB) or participation in standardization (STAND) or with a patent application (PAT) in 2010-2013 at OEM A or in 2003-2014 at OEM B. For OEM A, employees were selected if one has one patent application in 2008-2013 and a PhD title.

Multi-item scales were used to measure our constructs. In cases, where it was impossible to match the validated items from the literature to individuals' motives, we have adapted the items accordingly. To scale items (motives), we applied a 5-point Likert scale, where 1 corresponds to "totally disagree" and 5 to "totally agree".

The response rate for OEM A was at 23.9 % and for OEM B at 20.4 %. After the screening of the survey data and the elimination of outliers and entry errors, we could match the observations of OEM A, and OEM B obtained 1,118 usable questionnaires for performing our analyses. Although the amount of observations per item varies, we retain complete and incomplete cases for our analyses to prevent loss of information.

Our observed data consists of 75.49 % patent-filing employees (PAT), 37.30 % employees experienced in publication activities in relation to their work (PUB) and 17.44 % employees active in standardization on behalf of the company (STAND).

Table 1 shows the distribution of the activities of the respondents. Active in patenting and publishing are 32.20 %, and only 8.05 % are experienced in all activities. Hence 46.15 % of standardization experts have experience in patenting and publishing. Interestingly, 86.33 % of publishing employees file patents and only 42.65 % of patenting employees are experienced in publishing, too. More notably, among the activities in standardization, 15.76 % of employees active in patenting are experienced in standardization, whereas 68.21 % of employees active in standardization are filing patents, too. And 29.02 % of publishing employees are active in standardization; however, 62.05 % of standardization participants are experienced in publishing.

4. Results of Exploratory factor analyses

A principal component factor analysis was performed in three different parts of the questionnaire on motivations relating to the participation in patenting, standardization and for scientific publications activities. First, a ranking of the answers in every activity was made, and afterwards, factors were generated to show the motives of the activities. The internal reliability of the items grouped by factor analyses

Table 3
Ranking and exploratory factor analysis of patent motives.

Motives to patent	Rank	Obs.	Mean (SD)	F1	F2	F3	F4
Preservation of own technological development scope (freedom to operate)	6	744	3.81 (1.06)	0.51			
Increase corporate reputation	2	735	4.01 (1.01)	0.52			
Enhance position in business co-operations (with competitors, suppliers, or research institutions)	3	753	4.02 (0.86)	0.64			
Hinders competitors entering the market	8	754	3.3 (1.12)	0.62			
Prevention of imitation	5	781	3.92 (1.05)	0.70			
Gain competitive advantage (securing priority status)	1	789	4.48 (0.7)	0.75			
Patents are used as an internal performance indicator	11	783	2.85 (1.31)		0.53		
Increasing the external reputation of the employee	9	742	3.05 (1.16)		0.84		
Increasing the internal reputation of the employee	7	779	3.45 (1.11)		0.79		
Part of the individual performance agreement	15	738	2.10 (1.21)			0.61	
Patents increase income through royalties	14	496	2.82 (1.05)			0.81	
Attractive invention remuneration scheme	12	747	2.72 (1.21)			0.83	
Patents can be incorporated specifically in standardization development	10	607	3.04 (1.04)				0.74
Patents enable and facilitate spin-offs	13	776	2.93 (1.18)				0.74
Precise assignment of invention	4	780	3.95 (0.97)				

Notes: Ranking: The mean is the average on a 5-point Likert scale: answers between 1 (totally disagree) to 5 (totally agree).
SD = standard deviation.
Factor analysis method: principal-component factors with orthogonal varimax rotation. Obs.: 403. Kaiser-Meyer-Olkin measures overall 0.77. Explained variance: 0.58. Loadings between -0.5 and 0.5 are not displayed.

is tested by Cronbach's alpha coefficient.[2] Secondly, the factors are used for further analysis related to the different response groups for the different activities of publishing, patenting, and standardization.

Table 2 reports the descriptive statistics, ranking and factor analysis results of the employees' motives to participate in publication activities. The ranking of the motives to publish shows the three highest-ranking motives to publish are "carry forward the state of art in science and technology via reviews", "increase reputation of the company", and "are effective for dissemination of scientific knowledge". The lowest-ranked motives to publish are "part of the individual performance agreement", "are used as an internal performance indicator" and "scientific publishing promotes the professional preference", and therefore do not have a deep impact on the motive for the employees to participate in publishing activities.

Exploratory factor analysis identified three factors. The first group is representing the motive of *personal reputation and performance*. In the case of publishing motives, it includes the increase of reputation and the inclusion in individual performance agreements. With a Cronbach's alpha of 0.7, we can assume that the internal reliability of this factor is acceptable. The second factor, which we labelled *company reputation and scientific progress,* is related to the increase of: "companies' reputation", and "the promotion of state of the art in science and technology via reviews" and "effective for dissemination of scientific knowledge". Publishing scientific results is not only disseminating peer-reviewed scientific knowledge but also promoting companies' reputation. Again, the internal reliability for this factor is acceptable at the value of 0.7.

The third factor for the motives to publish is referring to *competitiveness and returns from publishing activities* and has high factor loadings on demonstrating the superiority of own technologies when competing or substitutable technologies are present, resulting from participation in conferences, workshops, research projects and consortia and assessment of patentability via corporate publication approval processes. Here, the reliability of this factor is rather unacceptable with a Cronbach's alpha of 0.3. However, we retain a Cronbach's alpha of 0.7, which is still acceptable, if we remove the item "result from participation in conferences, workshops, research projects and consortia" from this factor construct. The two separated factor analyses differentiated into the two OEMs in case of motives to publish are provided in Appendix Table 1.

Table 3 reports the descriptive statistics, ranking and factor analysis results of employees' motives to patent. The highest-ranked motive for filing patents for the employees taking part in the survey is "gain competitive advantage (securing priority status)", followed by "increase corporate reputation" and "enhance position in business co-operations (with competitors, suppliers or research institutions)". The lowest-ranked motives are "part of the individual performance agreement", "patents increase income through royalties", and "patents enable and facilitate spin-offs" and are therefore the lower motives for the employees filing patents.

The factor analysis generates four factors. The first factor relates to *securing competitiveness* by high-factor loadings of freedom to operate, increase reputation, enhance position in business co-operations, hindering competitors entering the market, prevention of imitation and gaining competitive advantage. The second group is the factor of the *personal reputation and performance* (see Blind et al., 2006), referring to the use of patents as an internal performance indicator and increasing the internal and external reputation. Both factors have a Cronbach's alpha of 0.7, which indicates acceptable internal reliability. The third factor shows the *financial incentives* for the employees through patenting activities, since they are part of individual performance agreements, can increase income through royalties and are an attractive invention remuneration scheme. Although this factor has a questionable reliability with an alpha of 0.6, it still can be an appropriate measurement for the underlying construct.

The fourth and last factor for the patent motives includes that *patents as basis for standardization and entrepreneurship* due to the possibility of patents to enable and facilitate spin-offs and precise assignment of invention. The Cronbach's alpha (0.7) indicates acceptable internal reliability of the factor. Separated factor analyses for both OEMs in case of motives to patent are provided in Appendix Table 2.

Table 4 reports the descriptive statistics, ranking and factor analysis results of the employees' motives to standardize. The highest ranked motives for participating in standardization is firstly "help to shape technically mature and industry-oriented standards", secondly "carry

[2] In the context of psychological survey item constructs, Cronbach's alpha seems to be an appropriate measure to report on the reliability of a test construct or to show the interrelatedness of the multiple items of respective item groups; except for item groups that cover logically/desirable constructs (Tavakol & Dennick, 2011).

Table 4
Ranking and exploratory factor analysis of standardization motives.

Motives to standardize	Rank	Obs.	Mean (SD)	F1	F2	F3	F4
Favoring the diffusion of own technology through standards (opening of markets)	12	173	3.40 (1.17)	0.56			
Certainty of technological development scope	11	173	3.42 (1.15)	0.61			
Preventions of regulations	14	172	3.35 (1.31)	0.65			
Observe the technical knowledge of other competitors (or market participants)	7	177	3.66 (1.09)	0.65			
Prevention of market power of proprietary de facto standards	10	163	3.52 (1.22)	0.70			
Prevention of standards and contents that contradict the interests of the company	4	178	4.04 (1.11)	0.75			
Guarantee safety in technology	5	179	4.00 (0.99)		0.53		
Generating new knowledge within standardization committees	9	183	3.56 (1.04)		0.62		
Help to shape technically mature and industry-oriented standards	1	186	4.34 (0.76)		0.68		
Integrate pre-normative results and competitively relevant research (into standardization)	13	170	3.37 (1.18)		0.71		
Carry forward state of art in technology	2	187	4.10 (0.93)		0.73		
Integration of own intellectual property rights on fair terms in standards	18	158	2.49 (1.21)			0.58	
(Addressing) technical problems and controlling development of technology	8	180	3.60 (1.11)			0.59	
Promoting interoperability with suppliers of complementary products	15	155	3.25 (1.26)			0.62	
Making contacts with potential partners for future (R&D) projects	16	169	3.25 (1.11)			0.68	
Contribute individual abilities for the benefit of the company	3	187	4.05 (0.97)				0.66
Is used as an internal performance indicator	19	173	2.20 (1.12)				0.71
Increase(technical/scientific) reputation of employee	17	182	2.95 (1.30)				0.76
Making contacts and cultivating networks	6	185	3.71 (1.03)				

Notes: Ranking: The mean is the average on a 5-point Likert scale: answers between 1 (totally disagree) to 5 (totally agree).
SD = standard deviation.
Factor analysis method: principal-component factors with orthogonal varimax rotation. Obs.: 123. Kaiser-Meyer-Olkin measures overall 0.82. Explained variance: 0.82. Loadings between -0.5 and 0.5 are not displayed.

forward state of art in technology", similar to the findings by Blind et al. (2018), and thirdly "contribute individual abilities for the benefit of the company". The lowest-ranked motives to participate in standardization are "is used as an internal performance indicator", "integration of own intellectual property rights on fair terms in standards" and "increase (technical/scientific) reputation of employee", and are seen as a less motivation for the employees to participate in standardization.

We also received four factors by the exploratory factor analysis. The first factor, *company interests,* represents employees' actions in the interest of the company to participate in standardization. We have high factor loadings on opening of markets, certainty of technological development scope, and preventions of regulations, observing the technical knowledge of other competitors, prevention of market power of proprietary de facto standards and prevention of standards and contents that contradict the interests of the company. The Cronbach's alpha of 0.8 indicates good internal reliability of this first factor. The second factor includes *the integration of state in the art in science and technology into standards* and is the factor that refers to the motive of standardization being related to the technology*:* generate new knowledge within standardization committees, help to shape technically mature and industry-oriented standards, integrate pre-normative results, competitively relevant research and carry forward state of the art in technology. Again, Cronbach's alpha of 0.8 indicates good internal reliability.

The third factor we labelled *managing network/interfaces of technology and partners via standardization* as it refers to the integration of own intellectual property rights on fair terms in standards, technical problems and controlling the development of technology, promoting interoperability with suppliers of complementary products and making contacts with potential partners for future (R&D) projects. Standardization has not been considered in the literature about academia-industry (e.g. Bhullar et al. 2019). The alpha of 0.7 shows acceptable internal factor reliability.

The last factor reports similar to the patent motive, *personal reputation and performance,* in the case of contributing individual abilities for the benefit of the company, increasing (technical/scientific) reputation of employees and usage as an internal performance indicator. This factor is similar to factor one of publishing and the second factor of patenting. Due to listwise deletion in measuring Cronbach's alpha, very few observations (in total: 28) lead to internal reliability of only 0.2. Yet, a three-factor solution that increases the number of items can help to increase the reliability of this item group. For a better interpretation of the factors, we want to rely on our four factors solution. The different factor analyses for the OEMs in cases of motives to standardize are provided in Appendix Table 3.

Appendix Table 4 shows the ranking of all factors. We ranked the factors over all questionnaire responses to see the importance of the different factors for every motive model. In the case of motives to publish the most important factor is *company reputation and scientific progress*, followed by *competitiveness and returns from publishing activities* and *personal reputation and performance*. For the motives to patent, the ranking of the factors is: first *securing competitiveness*, second *personal reputation and performance*, third *patents as basis for standardization and entrepreneurship* and last *financial incentives.* For the motives to participate in standardization, the factor *the integration of state in the art in science and technology into standards* is most important by the value of the mean, followed by the factor *company interest, managing network/interfaces of technology and partners via standardization* and *personal reputation and performance*.

Finally, the factors (and the underlying motives) of the three activities are sorted in Table 5 by 'Gold', 'Puzzle' and 'Ribbon' classifications with 'Gold' reflecting the *financial rewards*, 'Ribbon' the *carrier rewards* and *reputation* and 'Puzzle' the *intrinsic satisfaction* (Lam, 2011).

We do not link the researchers' motive on the pursuit of the company's aims to tangible individual financial interests but rather to contribute to solving technical or social problems (satisfy intrinsic motivation). The industrial researcher's contributions to a specific activity do not directly impact the individual's performance agreement, career rewards and the individual's financial rewards, respectively. Researchers' contributions are funded by their wages which covers contributions for specific activities in the name of the employer. In the case of patents, the inventor is paid additionally, and he is interested to secure the priority status of his own invention and to have a precise assignment of his contribution. Recognition from their scientific peers is generally seen as the remuneration for the publishing engineers.

For "Gold", the factor of motives to publish *competitiveness and returns from publishing activities* is identified. The underlying construct is based on the demonstration of the superiority of own technologies when competing or substitutable technologies are present, with the aim to forward state of the art via reviews. Regarding publishing in scientific journals, researchers invest in a higher value for the job market in the future and, therefore, higher salaries. Therefore, returns from publishing are extrinsic motivated financial rewards, the "Gold" (Sauermann & Roach, 2014). Motives to

Table 5
Observed Contribution of Publishing, Patenting and Standardization to 'Puzzle', 'Ribbon' and 'Gold'.

Contribution ofto	Publishing	Patenting	Standardization
'Puzzle' *intrinsic satisfaction*			FR1: Integration of state of the art into standards (STAND Factor 2)
'Ribbon' *career rewards and reputation*	FR1: Company reputation and scientific progress (PUB Factor 2) FR3: Personal reputation and performance (PUB Factor 1)	FR2: Personal reputation and performance (PAT Factor 2)	FR4: Personal reputation and performance (STAND Factor 4)
'Gold' *financial rewards*	FR2: Competitiveness and returns from publishing activities (PUB Factor 3)	FR1: Securing competitiveness (PAT Factor 1) FR3: Patents as basis for standardization and entrepreneurship (PAT Factor 4) FR4: Financial incentives (PAT Factor 3)	FR2: Company interest (STAND Factor 1) FR3: Managing networks/ interfaces (STAND Factor 3)

FR= Factor Rank, ranked by mean, see Appendix Table 4.

patent that summarize *financial incentives* are also assigned to "Gold" as well as *securing competitiveness* and *patents as basis for standardization and entrepreneurship*. The motives to publish, patent and standardization that form the underlying factor construct of *personal reputation and performance* are linked to career rewards and reputation, the "Ribbon". In addition, concerning publishing, the motives that are allocated to the factor *company reputation and scientific progress* are attributed to "Ribbon". For motives to standardize, we see the most factors as "Puzzle" contribution: *company interests, the integration of state in the art in science and technology into standards* and *managing networks and interfaces of technology and partners via standardization.* The engineers are likely to have a high interest in the activity itself and then the benefits of the activity to pursue the aims of the company. This leads to the assumption that standardization is a more 'Puzzle' activity, like for scientists in public research institutes (Blind et al. 2018).

Now, we turn to answerour three research questions. First, regarding scientific publishing, the results of the factor analysis reveal that the intrinsic motivations are most important for the engineers in industry. In contrast, the reputation from the scientific community is of least importance, with the financial motivation having a medium relevance. Compared with the academics surveyed by Blind et al. (2018), the intrinsic motivation of researchers in the industry to publish scientific articles is higher rated. Obviously, this intrinsic motivation is needed in order for them to spend time in writing articles, because they do receive neither the same level of positive feedback from the scientific community nor financial rewards from their current employer.

Turning secondly to the motives to patent, engineers assess both financial and reputational effects at the same level of relevance, which is quite similar to the response pattern of the employees of the public research institutes (Blind et al. 2018) and insights from other surveys among academics (see the section in the literature survey). This similarity can be explained, at least for Germany, that the institutional framework conditions are the same for inventors both in companies and public research institutes according to the German Employees' Inventions Act. Other countries have similar laws, which do not distinguish between public and private organizations as employers of inventors. The financial compensation can be higher within the industry, but Giummo (2014) reveals that around two thirds of the patents in his sample of around 1,000 patents had a value of less than 5000 DM, i.e. 2,500€. Already Leptien (1995) reports a high level of dissatisfaction with the compensation provided under the act, but also with the time lag between the invention and the compensation and the lacking transparency of the compensation scheme. In addition, patenting both in industry and public research organizations benefit from large structural support and organizational tools, like patent departments or technology transfer offices. Overall, the external and internal framework conditions for patenting in industry and public research organizations are quite similar, which is also reflected in a similar relevance of the motivations either linked to financial rewards or reputation.

Thirdly, the ranking of the motives to get involved in standardization are both among researchers in industry and academia is headed by intrinsic motivations. This finding is in line with the strong intrinsic motivation of researchers in coopetitive R&D alliances (Wang et al. 2019), to which standardization consortia can also be attributed to (Blind and Mangelsdorf 2013). In industry, the financial incentives are slightly higher rated than the reputation related motives, whereas in a research institute analyzed by Blind et al. (2018), "Ribbon" is more a driver than "Gold". The explanation of the strong intrinsic motivation to standardize both in industry and public research institutes goes again back to similar framework conditions. In contrast to patenting, for which an external regulatory framework exists, and internal support structure have been established, there is neither an institutional framework nor an elaborated organizational support for researchers' involvement in standardization in industry and public research institutes. Therefore, a strong intrinsic motivation is needed, like for industry researchers regarding scientific publishing. Financial incentives are strong for inventors in the area of information and communication technology due to the possible revenue to be generated via standard-essential patents. However, such patents are still quite rare in the automotive industry and non-existent in the material science institute investigated by Blind et al. (2018), which has, however, contribution to standards integrated into its mission. Therefore, participating in standardization promotes the reputation of researchers.

Finally, answering the three questions above related to industry researchers' motives to publish, patent and standardize in comparison with those in public research organizations allows us to come to a more general insight related to our fourth research question. Obviously, researchers' organizational environment influence their motives to publish, patent and standardize. Similar regulatory framework conditions and internal support for patenting is reflected in similar answers by researchers in industry and public research organizations. Missing legal frames and likewise limited support, like in the case of standardization, requires for researchers in industry and public research institutes strong intrinsic incentives. This is also the case for scientific publishing of researchers in the industry, because they experience only limited positive feedback from the research community and cannot expect financial rewards or promotion based on their publications in scientific journals. This is in contrast to researchers' environment in public research organizations or universities, which reduces their need for a strong intrinsic motivations. Overall, the interpretation of researchers' motives to publish, patent, and standardize has to take into account not only the organizational framework conditions set up by their employers, but also the general regulatory framework conditions and responsiveness of the relevant (research) community.

5. Discussion and Conclusion

5.1. Theoretical Implications

In the taxonomy of different forms of openness in the context of open innovation by Dahlander and Gann (2010), the revealing of ideas is classified as non-pecuniary outbound innovation. Scientific publications, but also the contributions to standards, are therefore forms of outbound innovation. Even patents reveal ideas, but patenting is in general attributed to protecting and selling ideas. Although, sometimes, companies allow other companies to use their patents for free. However, the latter forms have not been considered in the context of open innovation. Therefore, we contribute with our study also to the large body of literature on open innovation.

Whereas at the company level, the motivations to publish, to patent and to standardize have been analyzed, we start to close this research gap by providing complementary insights about the motivations of individual engineers. Finally, our study reveals insights, which complement the findings based on the assessments of researchers in a publicly financed research institute (Blind & Gauch, 2009; Zi & Blind, 2015, Blind et al. 2018).

At first, the comparison between our findings on individual engineers' motivations related to publishing, patenting and standardization with insights on companies' strategies reveals the following pattern. The dominant motive of "Ribbon" by individual engineers to publish scientific articles is only directly linked to firms' motive to publish in order to stay involved in the scientific community and to attract or retain scientists for their research departments. However, publishing has also to be aligned to signalling the company's capacity to other stakeholders, but also to its IPR and commercialization strategy. Obviously, there is a gap to close between individual engineers' motives and companies' publication strategies.

Related to patenting, the dominant motive of "Gold" of individual inventors can be more easily coordinated with companies' strategies to patent, like protecting own inventions, blocking competitors, using patents as barter chips in exchange with other stakeholders, like banks or licensees, as incentives for employees and as performance indicators.

Finally, the high relevance of "Puzzle" for those engaged in standardization cannot easily be connected to companies' standardization strategies, like knowledge-seeking, facilitating market access, influencing regulation and enforcing companies own interests. Only the solution of technical problems via standardization is close to "Puzzle". Overall, there are several gaps between companies' motives and those of individual engineers to publish, to patent and to standardize, which call at first for in-depth and comprehensive conceptual analyses.

Secondly, we provide first inputs to a basic framework of motivational research regarding publishing, patenting and participation in standardization. These three activities have not yet been analyzed in a sufficient, comprehensive way. However, they are well-established strategic instruments for R&D activities, knowledge management and innovation activities for academics and researchers employed by commercially active companies. We reveal basic insights into engineers' inclination towards participation in standardization. These findings are contrasted with their preferences for publishing and patenting. The observed distribution of engineers' activities indicates that there is a substantial imbalance in the way that industrial researchers assess their contribution to publishing, filing patents and participating in standardization. By comparing these insights to the motivations of researchers in public research organizations and universities, we reveal a general pattern. First, if the external framework conditions and the internal support provided by the employing organizations are similar, such as in the case of patenting in Germany, we observe similar patterns with regards to the motivations driving researchers employed in private or public organizations. Second, if these external incentives are rather strong and established, intrinsic motivation is less relevant for researchers to get engaged. Third, if both the external framework as well as internal support are missing, strong intrinsic incentives are needed for researchers to get engaged. This is the case for the participation in standardization both in most private companies and public research organizations, but also for publishing by researchers in industry, who have neither broad internal support and incentives nor external sources of positive feedback, e.g. from the research community.

Furthermore, the puzzling results of the studies about the diverging trends in scientific publishing (Arora et al. 2018; Camerino et al. 2018), patenting (Fink et al. 2016) and standardization (Baron & Spulber, 2018) only considered the company, but not the individual researchers' perspective. Our insights might be used to inform both these findings, but also future studies, which should take both institutional framework conditions, companies' strategies and individual researchers' motivations into account.

Finally, since publishing, patenting and standardization activities of engineers have important implications on technological change, our findings provide some insights about the impacts on and possible directions of technological change depending on the motivations of the researchers.

First, scientific publications and their knowledge as output both of basic and applied research are available for all interested researchers employed both at the public and private sector and can promote technical change in general, but due to their broad relevance for the SDGs also sustainability in general. Since policymakers responsible for research and innovation policy realign their objectives, e.g. in the context of mission-oriented innovation policies, towards the SDGs, the science and research communities have also adapted their objectives, i.e. topics addressing the SDGs enjoy higher levels of attention and eventually reputation.

Second, patenting activities driven by gold are also disclosing in particular commercially applicable technological knowledge, which general use is, however, restricted. Therefore, the potential contribution of patents to technological change is compared to scientific publications lower and mainly focused on SDG 9 on "Industry, Innovation and Infrastructure". Indirectly, the realignment of companies' strategies towards sustainability, in general, has also implications on their patenting strategy, which is eventually via financial incentives also influencing inventors' efforts related to patenting.

Third, the content of standards, like of scientific publications, is, in general, accessible to and applicable by all interested organizations, in particular companies and, therefore, driving technological change. The strong intrinsic motivation of researchers to join standardization activities will generate mainly to standards related to SDG 9 "Industry, Innovation and Infrastructure", but also to several other SDGs, depending on their companies' sustainability strategies, because of the second most important motivation factor of company interest.

Overall, researchers' motivation in industry, but also research and technology organizations related to publishing, patenting and standardization has both influences on the speed of technological changes and the direction of technological change, in particular related to sustainability.

5.2. Managerial Implications

For companies, our insights might be used in a first step to making use of the engagement of the intrinsically motivated researchers, e.g. for the publishing of research results in order to secure companies' freedom to operate, i.e. being not restricted by patent rights of competitors. In addition, these insights support a more strategic involvement in standardization by companies in order to position their own technology in international standards as well as to prohibit standards based on competitors' technologies being established. In a second step, intra-organizational structures might be established, e.g. support and financial incentives, which could attract further researchers with lower intrinsic motivation to get involved in these activities. In the case of standardization, public research organizations could benefit in the same way from these insights, e.g. by expanding the support for standardization activities by their technology transfer offices.

Finally, the insights can be used for the recruitment and further promotion of researchers. First, researchers with a strong publication record are likely to be strongly motivated by the reputation of the scientific community. One implication could be to give these researchers some leeway to continue their publishing activities embedded, for example, in the company's intellectual property strategy, e.g. for defensive publications preventing competitors' successful patenting. Another implication of the findings is that applicants with a strong track record in patenting are obviously significantly motivated by financial incentives. However, the insights from previous studies reveal the limited financial incentives provided under the German Employees' Inventions Act. Consequently, if companies are interested in increasing the number of their patent applications, explicit and significant financial incentives have to be offered to new researchers to be hired. Related to standardization, the strongly intrinsic motivation of researcher involved in standardization, it is challenging to hire appropriate researchers for this task. Furthermore, Wang et al. (2019) reveal a three-way interaction between job experience, central network position and intrinsic motivation of researchers on their performance in coopetitive R&D alliances, being similar to standardization consortia. Consequently, it makes sense for companies that these researchers collect some experience in their job and position themselves in formal R&D networks before they participate actively in standardization bodies.

5.3. Limitations

However, our research is limited to a sample of researchers employed at two German OEMs. It does not allow for sectoral or cross-sectoral general conclusions due to the specific characteristics of the respondents' environment. Therefore, this explorative study has to be expanded by further investigations covering other sectors and countries, but also small and medium-sized companies. Furthermore, these studies should also cover the interactions of the three types of activities, e.g. as with standard-essential patenting or publishing (Blind & Fenton, 2021; Blind et al., 2019). The comparison between the results based on the respondents employed at the two OEMs and the researchers working for a publicly-funded material science institute (Blind et al. 2018) is only of qualitative nature. The comparison has to be expanded to a large scale survey approach covering different sector and science fields and researchers both in industry and public research organizations or universities. The responses would then allow rigorous statistical comparisons and the testing of hypotheses, such as those conducted by Lam (2011), Ryan (2014), Perry et al. (2016) and Suominen et al. (2021), to validate the presented results and develop the most appropriate comprehensive framework of motivational drivers for researchers both employed in the private and public sector. Further insights about engineers' and scientists' motivations related to these activities might allow one to derive recommendations for the improvement of their collaborations in common research projects. Unfortunately, our surveys conducted in 2014 and 2015 could not consider the extension of Lam's framework to "mission" motivation by Iorio et al. (2017) or 'moral' motivation by Van de Burgwal et al. (2019)

A further extension would be the application of the motivation-opportunity-ability framework, e.g. applied by Wang et al. (2019), by collecting more information about the researchers' abilities, i.e. skills and experience, and opportunities, i.e. their positioning in professional networks. This would be then the basis to investigate the impact of these dimensions on the researchers' performance in publishing, patenting and, in particular, standardization, which is due to missing simple performance measures, a specific challenge.

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Conflict of interest statement

Manuscript title: Motives to Publish, to Patent and to Standardize: An Explorative Study Based on Individual Engineers' Assessments

Knut Blind certifies that he has NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ellen Filipović has also no conflict in interest, but has been employee of one of the OEMs investigated.

Luisa K. Lazina has also no conflict interest, but is still employed by one of the OEMs investigated.

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Appendix Table 1

Table 1: Ranking and exploratory factor analysis of publishing motives: OEM A and OEM B.

	OEM A			OEM B			OEM A				OEM B			
Motives to publish	Rank	Obs.	Mean (SD)	Rank	Obs.	Mean (SD)	F1	F2	F3	F4	F1	F2	F3	F4
Increase reputation of the employee	5	145	3.55 (0.93)	5	198	3.53 (1.04)	0.74				0.56			
Part of the individual performance agreement	11	143	1.59 (0.98)	11	190	1.47 (0.95)	0.68				0.64			
Scientific publishing promotes the professional preference Facilitate career and job opportunities	9	132	2.73 (1.06)	8	184	2.95 (1.21)	0.72				0.72			
Are used as an internal performance indicator	10	143	2.25 (1.10)	10	197	2.50 (1.18)	0.84				0.86			
Increase reputation of the company	2	145	4.06 (0.75)	2	207	4.17 (0.86)		0.82				0.52		
Carry forward the state of art in science and technology via reviews	1	145	4.14 (0.73)	1	207	4.18 (0.84)		0.71			0.00	0.83	0.00	0.00
Are effective for dissemination of scientific knowledge	3	143	3.96 (0.80)	3	203	3.99 (0.88)		0.80				0.86		
To demonstrate the superiority of own technologies when competing or substitutable technologies are present	4	143	3.57 (0.88)	6	196	3.42 (1.09)			0.71				0.65	
Reviews of scientific publications (from third parties) carry forward the state of art in science	6	150	3.48 (1.13)	4	206	3.53 (1.18)			0.83				0.83	
Result from participation in conferences, workshops, research projects and consortia	7	144	3.13 (1.22)	7	197	2.95 (1.24)				0.75			-0.56	
Assessment of patentability via corporate publication approval process	8	149	3.02 (1.12)	9	201	2.84 (1.24)				0.66				0.86

Notes: Ranking: The mean is the average on a 5-point Likert scale: answers between 1 (totally disagree) to 5 (totally agree). SD = standard deviation.
Factor analysis method: principal-component factors with orthogonal varimax rotation. Obs.: 121/156. Kaiser-Meyer-Olkin measures overall 0.66/0.68. Explained variance: 0.66/0.67. Loadings between -0.5 and 0.5 are not displayed.

Appendix Table 2

Table 2: Ranking and exploratory factor analysis of patent motives: OEM A and OEM B.

	OEM A			OEM B			OEM A				OEM B			
Motives to patent	Rank	Obs.	Mean (SD)	Rank	Obs.	Mean (SD)	F1	F2	F3	F4	F1	F2	F3	F4
Preservation of own technological development scope (freedom to operate)	6	313	3.80 (1.05)	6	431	3.82 (1.07)	0.50				0.54			
Increase corporate reputation	2	308	3.98 (1.03)	3	427	4.04 (0.99)					0.57			
Enhance position in business co-operations (with competitors, suppliers or research institutions)	3	323	3.98 (0.83)	2	430	4.06 (0.89)	0.66				0.60			
Hinders competitors entering the market	8	318	3.32 (1.07)	8	436	3.28 (1.17)	0.63				0.63			
Prevention of imitation	5	326	3.86 (1.07)	5	455	3.96 (1.04)	0.69				0.70			
Gain competitive advantage (securing priority status)	1	327	4.46 (0.72)	1	462	4.48 (0.69)	0.75				0.71			
Patents are used as an internal performance indicator	11	329	3.00 (1.33)	13	454	2.74 (1.28)			0.58			0.53		
Increasing the external reputation of the employee	9	316	3.16 (1.06)	10	426	2.96 (1.23)			0.81			0.84		
Increasing the internal reputation of the employee	7	328	3.50 (1.03)	7	451	3.42 (1.16)			0.75			0.84		
Part of the individual performance agreement	15	311	2.17 (1.13)	15	427	2.05 (1.26)		0.60					0.61	
Patents increase income through royalties	14	242	2.89 (0.99)	12	254	2.75 (1.10)		0.83					0.80	
Attractive invention remuneration scheme	12	317	2.97 (1.18)	14	430	2.53 (1.21)		0.83					0.81	
Patents can be incorporated specifically in standardization development	10	274	3.09 (0.92)	9	333	2.99 (1.13)				0.67				0.76
Patents enable and facilitate spin-offs	13	325	2.90 (1.11)	11	451	2.95 (1.22)				0.71				0.78
Precise assignment of invention	4	321	3.93 (0.93)	4	459	3.97 (1.00)								

Notes: Ranking: The mean is the average on a 5-point Likert scale: answers between 1 (totally disagree) to 5 (totally agree).

SD = standard deviation.

Factor analysis method: principal-component factors with orthogonal varimax rotation. Obs.: 191/212. Kaiser-Meyer-Olkin measures overall 0.71/0.77. Explained variance: 0.55/0.61. Loadings between -0.5 and 0.5 are not displayed.

Appendix Table 3

Table 3: Ranking and exploratory factor analysis of standardization motives: OEM A and OEM B.

	OEM A			OEM B			OEM A			OEM B				
Motives to standardize	Rank	Obs.	Mean (SD)	Rank	Obs.	Mean (SD)	F1	F2	F3	F4	F1	F2	F3	F4
Favoring the diffusion of own technology through standards (opening of markets)	14	63	3.37 (1.21)	10	110	3.42 (1.14)		0.59						0.68
Certainty of technological development scope	12	61	3.44 (1.06)	11	112	3.41 (1.20)		0.61				0.73		
Preventions of regulations	15	63	3.32 (1.41)	13	109	3.38 (1.25)		0.58						0.75
Observe the technical knowledge of other competitors (or market participants)	6	63	3.79 (0.99)	7	114	3.58 (1.14)		0.82			0.77			
Prevention of market power of proprietary de facto standards	8	58	3.71 (1.15)	12	105	3.41 (1.25)		0.59		0.59	0.59			
Prevention of standards and contents that contradict the interests of the company	2	65	4.17 (1.05)	5	113	3.97 (1.15)		0.67			0.56			
Guarantee safety in technology	5	64	3.94 (0.99)	4	115	4.03 (0.99)	0.58							0.59
Generating new knowledge within standardization committees	11	65	3.58 (1.04)	9	118	3.54 (1.03)	0.67					0.72		
Help to shape technically mature and industry-oriented standards	1	66	4.55 (0.59)	1	120	4.23 (0.82)				0.59		0.74		
Integrate pre-normative results and competitively relevant research (into standardization)	10	64	3.61 (1.15)	15	106	3.23 (1.17)	0.59					0.62		
Carry forward state of art in technology	3	66	4.00 (0.94)	2	121	4.15 (0.92)	0.63			0.57		0.56		
Integration of own intellectual property rights on fair terms in standards	18	60	2.47 (1.14)	18	98	2.50 (1.26)			0.53		0.60			
(Adressing) technical problems and controlling development of technology	9	65	3.69 (1.09)	8	115	3.55 (1.12)			0.75					0.55

(*continued on next page*)

Appendix Table 3 (*continued*)

Promoting interoperability with suppliers of complementary products	13	58	3.41 (1.28)	16	97	3.15 (1.24)			0.70				
Making contacts with potential partners for future (R&D) projects	16	63	3.24 (1.01)	14	106	3.25 (1.17)			0.65		0.68		
Contribute individual abilities for the benefit of the company	4	66	3.95 (1.06)	3	121	4.11 (0.91)	0.77					0.53	0.58
Is used as an internal performance indicator	19	64	2.13 (1.13)	19	109	2.24 (1.11)	0.64						0.65
Increase(technical/scientific) reputation of employee	17	65	2.97 (1.17)	17	117	2.94 (1.37)	0.73						0.74
Making contacts and cultivating networks	7	66	3.76 (1.01)	6	119	3.69 (1.05)				0.71			0.51

Notes: Ranking: The mean is the average on a 5-point Likert scale: answers between 1 (totally disagree) to 5 (totally agree).
SD = standard deviation.
Factor analysis method: principal-component factors with orthogonal varimax rotation. Obs.: 51/72. Kaiser-Meyer-Olkin measures overall 0.75/0.76. Explained variance: 0.61/0.56. Loadings between -0.5 and 0.5 are not displayed.

Appendix Table 4
Table 4: Ranking of factors

	Contribution	Ranking FR	Obs.	Mean (SD)
Motives to publish				
Personal reputation and performance	Ribbon	3	357	2.62 (0.85)
Company reputation and scientific progress	Puzzle	1	357	4.09 (0.65)
Competitiveness and returns from publishing activities	Gold	2	351	3.35 (0.72)
Motives to patent				
Securing competitiveness	Gold	1	799	3.93 (0.63)
Personal reputation and performance	Ribbon	2	793	3.15 (0.95)
Financial incentives	Gold	4	797	2.55 (0.96)
Patents as basis for standardization and entrepreneurship	Gold	3	633	2.94 (0.96)
Motives to standardize				
Company interests	Gold	2	186	3.56 (0.83)
The integration of state in the art in science and technology into standards	Puzzle	1	189	3.89 (0.70)
Managing network/interfaces of technology and partners via standardization	Gold	3	183	3.19 (0.88)
Personal reputation and performance	Ribbon	4	189	3.11 (0.90)

Notes: Ranking: The mean is the average on a 5-point Likert scale; answers between 1 (totally disagree) to 5 (totally agree). SD = standard deviation. FR=Factor rank.

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