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Too much or too little of R & D offshoring: The impact of captive offshoring and contract offshoring on innovation performance

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ABSTRACT

Innovating firms may acquire foreign knowledge and improve their innovation performance by offshoring their R & D activities to their own foreign affiliates (captive offshoring) as well as by contracting out their R & D to external foreign parties (contract offshoring). This study examines the impact of both R & D offshoring strategies on innovation performance. Based on a panel dataset of 2421 R & D-active firms in Germany, we demonstrate that captive offshoring and contract offshoring differ fundamentally in their impact on firm innovation performance. At low degrees of offshoring, contract offshoring positively affects innovation performance and is preferable over captive offshoring. At larger degrees of offshoring, captive offshoring becomes more beneficial while contract offshoring is disadvantageous. Both offshoring strategies eventually harm innovation performance when excessively employed. Furthermore, the R & D offshoring-performance relationship is leveraged by R & D intensity, such that firms with a larger knowledge stock benefit stronger from both captive and contract offshoring.

1. Introduction

Offshoring research and development (R & D) allows innovating firms to tap into foreign knowledge resources, which subsequently contributes to their innovation performance and competitive advantage (Bertrand and Mol, 2013; Mihalache et al., 2012; Nieto and Rodríguez, 2011; Rodríguez and Nieto, 2016). Innovating firms can employ different R & D offshoring strategies: *Contract offshoring R & D* implies that firms outsource R & D to external foreign parties. *Captive offshoring R & D* implies they conduct R & D activities in their own foreign affiliates (Manning et al., 2008; Mudambi, 2008).[1] While previous research emphasizes the antecedents to offshoring innovation activities (e.g., Lewin et al., 2009; Manning et al., 2008; Martínez-Noya and García-Canal, 2011), less is known about the R & D offshoring-performance relationship (Mihalache et al., 2012; Mihalache and Mihalache, 2016). In particular, we have only limited knowledge about the potentially different effects that contract offshoring and captive offshoring have on a firm's innovation performance (Nieto and Rodríguez, 2011; Rodríguez and Nieto, 2016). We contribute to this research by theoretically and empirically demonstrating that these offshoring strategies have fundamentally different impacts on the innovation performance of firms.

Captive offshoring as an individual strategy is rarely isolated in previous analyses. On the one hand, studies on *R & D outsourcing* compare in-house and outsourced activities (Berchicci, 2013; Bönte, 2003; Grimpe and Kaiser, 2010) without explicitly differentiating whether these in-house R & D activities are offshore (i.e., captive offshoring R & D) or domestic. On the other hand, studies on *R & D offshoring* focus on the difference between domestic versus offshore R & D (Mihalache et al., 2012) without distinguishing between in-house R & D offshoring (i.e., captive offshoring R & D) and outsourced R & D offshoring (i.e., contract offshoring R & D). As captive offshoring is pooled either with internal domestic R & D or with contract offshoring, there is a lack of attention toward the potential particularities of captive offshoring. Although managers recognize that captive offshoring is an important

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[1] Please note, in other research papers contract offshoring R & D is also referred to as offshore outsourcing (Mihalache and Mihalache, 2016; Nieto and Rodríguez, 2011; Rodríguez and Nieto, 2016) and external offshoring (Tamayo and Huergo, 2017). Similarly, captive offshoring (Chandok et al., 2013) is also referred to as offshore insourcing (Rodríguez and Nieto, 2016) and internal offshoring (Tamayo and Huergo, 2016).

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strategic option[2] (Chandok et al., 2013), its value is not well understood in the academic literature. Specifically, the extent to which firms use this R & D offshoring strategy and its unique performance implications are often overlooked. This lack of attention limits theory development and might even lead to seriously biased managerial implications.

With respect to the analysis of captive offshoring R & D, Nieto and Rodríguez (2011) argue that due to strategy-specific costs and benefits, firms' innovation performance will be higher when they engage in captive offshoring R & D rather than in contract offshoring R & D. Does this result imply that returns to offshoring are always positive, even with very high offshoring degrees, and, should the offshoring of R & D activities always be implemented through captive offshoring rather than contract offshoring? Some evidence to answer the first part of the question is provided by Mihalache et al. (2012), who demonstrate − without separating captive and contract offshoring − that offshoring innovation-related business functions[3] negatively affects firm innovation performance at higher degrees of offshoring. At higher degrees of offshoring, domestic headquarters may lack the expertise and ability to efficiently absorb the knowledge accessible at geographically and culturally distant locations, which eventually implies that only intermediate degrees of offshoring are optimal (Mihalache et al., 2012). With respect to the second part of the question, there is also evidence that captive offshoring to affiliated firms negatively affects firm innovation performance (Bertrand and Mol, 2013). Beyond such conflicting results, we also do not yet know whether, and to what extent, the two offshoring strategies might suffer differently from being excessively used, such that captive and contract offshoring may reach their optima at substantially different degrees. Due to differences in transaction costs, captive offshoring as internal strategy might be more effective in reaping the benefits of offshoring, especially at degrees where contract offshoring as market strategy might reach its limits.

Revisiting theories explaining the effects of offshoring and outsourcing on innovation performance allows us to highlight important differences in how captive and contract offshoring R & D affect firm innovation performance. Specifically, and consistent with both Grimpe and Kaiser (2010) and Mihalache et al. (2012), we argue that a relative increase in contract offshoring has a positive effect on innovation performance for lower degrees of offshoring, but only up to an intermediate threshold; thereafter higher degrees display a negative effect. In contrast, we argue that a relative increase of captive offshoring has a negative effect on innovation performance for lower degrees, which, after a critical threshold is met, turns positive. Nevertheless, for very high degrees of captive offshoring, we again expect a decline in innovation performance, which would be consistent with the negative effect predicted by Mihalache et al. (2012) in the case of excessive offshoring. However, due to differences in coordination costs, we suggest that the optimal degree of captive offshoring is much higher than the optimal degree for contract offshoring. Using firm-level data for 2421 German R & D-active firms between 2005 and 2011, we test and largely confirm our predictions. The results remain robust for various alternative specifications and across different industry sample splits.

By theoretically and empirically highlighting the specific pattern of the relationship between captive offshoring R & D and innovation performance, our study contributes to research on offshoring of innovation (e.g., Bertrand and Mol, 2013; Mihalache et al., 2012; Nieto and Rodríguez, 2011). With respect to managing R & D offshoring, Mihalache et al. (2012) emphasize that management needs to refrain from excessive offshoring. We complement their results and emphasize that the critical threshold (after which the returns to offshoring decline) is much higher for captive than for contract offshoring. No less important when managing captive offshoring, managers also need to ensure they achieve a sufficient scale that results in positive returns. Entering at a too small scale might result in the strategy being less effective than it could be or even decrease firm innovation performance.

Furthermore, firms' investments in their knowledge stock (R & D intensity) are argued to facilitate the transfer, integration, and commercialization of external knowledge (e.g., Berchicci, 2013; Grimpe and Kaiser, 2010). Previous research demonstrates this for R & D outsourcing, which includes R & D contract offshoring. We demonstrate that captive offshoring is also facilitated by better integrative abilities; that is, intra-firm knowledge transfers from foreign to domestic locations also benefit from higher R & D intensities. In sum, we believe that this study highlights important managerial challenges and performance implications related to R & D offshoring and, in particular, to captive offshoring.

2. Theoretical background and hypothesis development

2.1. Offshoring and firm innovativeness

Offshoring R & D activities to foreign countries can help firms to tap into foreign knowledge and resources, like highly qualified personnel, to improve their knowledge stocks (Florida, 1997; Kuemmerle, 1999; Lewin et al., 2009; Maskell et al., 2007) and to avoid delayed access to important technological developments (Gerybadze and Reger, 1999; Hedlund, 1986). The resulting improvements in the knowledge stock leverages firms' innovation performance, i.e., the introduction of products and services that are new to the firm (e.g., Cohen and Levinthal, 1990; Kotabe et al., 2007), thereby securing both their competitive advantage and their future growth prospects (Banbury and Mitchell, 1995). Firms can additionally benefit from R & D offshoring because it may help them to reduce costs, for example, through the utilization of cross-border wage differentials (Massini et al., 2010), which in turn allows for more innovation activities at a given R & D budget.

Offshoring, however, does not come without risks. In particular, if excessively employed, offshoring can harm firms' innovation performance (Mihalache et al., 2012). Firms' ability to recognize the value of new knowledge, then to assimilate and to apply it, is key for their innovation output. Hence, in the case of offshoring, firms need sufficient domestic R & D personnel and investments in order to integrate foreign knowledge into the firm's general knowledge stock (Cohen and Levinthal, 1990). Excessive offshoring can hollow out a firm, thereby preventing the firm from internalizing foreign knowledge accessed through offshoring, which, in turn, may reduce the firm's innovation performance (Teece, 1987). Thus, positive effects of offshoring depend on a sufficient level of domestic R & D, which reflects a positive complementarity between domestic and offshore R & D. The reduced ability to integrate foreign knowledge can be further damaged by the complexities of managing high degrees of offshoring. Managerial attention might rather be diverted to the coordination of geographically dispersed R & D sites than to the actual integration of foreign R & D knowledge that could advance existing product lines and services (Mihalache et al., 2012). The complementarity between offshored and domestic R & D as well as the diseconomies of offshoring may render very high degrees of offshoring ineffective in fostering a firm's innovation performance.

Hypothesis 1a. *Firm innovation performance increases with contract offshoring up to a threshold after which innovation performance declines.*

Hypothesis 1b. *Firm innovation performance increases with captive offshoring up to a threshold after which innovation performance declines.*

[2] According to a 2013 survey by McKinsey of 1200 business leaders, it is exactly this particular type of R & D offshoring that is expected to increase substantially in the future (Chandok et al., 2013). Sixty-five percent of the respondents plan to increase staff at their offshore location by at least 15 percent in the next two to three years.

[3] Michalache et al. (2012) refer to business functions that provide direct knowledge inputs for innovation (i.e., production, R & D and engineering).

2.2. Strategy-specific drawbacks to offshoring

As discussed above, previous research convincingly argues for the existence of general limits to the benefits of R & D offshoring (Mihalache et al., 2012). Going a step further, we argue that the different strategies used to implement R & D offshoring, that is, captive offshoring and contract offshoring, are each differently affected by these threats to offshoring. Consequently, the optimal degree of offshoring might substantially differ between these two strategies.

Important factors responsible for the inability to scale offshoring to extreme degrees, as outlined by Mihalache et al. (2012), are amplified when offshoring is implemented through contract offshoring. In particular, contract offshoring causes various agency- and transaction-related issues: Managing information asymmetries, confidentiality, and intellectual property rights for outsourced R & D can lead to problems in partner selection, steering, and controlling (Grimpe and Kaiser, 2010). Policing, enforcement, and monitoring costs rise with strategic importance and the frequency of partnership interactions (Dyer and Singh, 1998; Gulati and Singh, 1998), such that these costs become particularly cumbersome for higher degrees of contract offshoring R & D. These transaction costs may even be higher in the cross-border context due to the geographical, cultural, and institutional distances between partners (Ambos and Ambos, 2009; Markides and Berg, 1988; Shenkar, 2001 Zaheer, 1995). In contrast to contract offshoring, and due to internalizing the foreign R & D activities, captive offshoring reduces and even circumvents some of these agency costs (Mudambi, 2008).

Likewise, threats related to information leakage, incomplete contract fulfillment, and clients becoming future competitors (Ellram et al., 2008; Kogut and Zander, 1993; Lai et al., 2009; Pisano, 1990) are higher for contract offshoring than for captive offshoring. Kogut and Zander (1993) emphasize that keeping the R & D system inside firm boundaries is a better way to prevent such leakages.

Moreover, for high degrees of offshoring, firms might more effectively manage their knowledge internalization processes by choosing an internal offshoring strategy. Captive offshoring might be better suited to reduce risks related to uncertainty, complexity, information asymmetry, bounded rationality, and opportunism (cf., Buckley and Casson, 1976). Furthermore, keeping the offshored R & D-activity inside firm boundaries may positively affect firm's internal knowledge stock because transferring, integrating, and commercializing new foreign knowledge is much easier. Thus, the risk of becoming a "hollow"-corporation, which is a firm with an insufficient internal knowledge stock and stagnating expertise (Kotabe and Mudambi, 2009; Mihalache et al., 2012), is minimized, while agency-related issues are substantially mitigated (Grimpe and Kaiser, 2010).

While captive offshoring may reduce problems related to transaction costs, information leakage, risks associated with transferring valuable, firm-specific knowledge to foreign players, and hold-up problems resulting from client-specific R & D investments (Nieto and Rodríguez, 2011), captive offshoring also has its limits. Despite being within own firm boundaries, geographic distance may still hamper the intra-firm flow of information (Teece, 1987). The integration of knowledge generated at foreign R & D sites may suffer from the 'not invented here' syndrome (Katz and Allen, 1982; Mihalache et al., 2012), as domestic R & D personnel might perceive foreign activities as competitive pressure. Hence, while captive offshoring might allow firms to successfully operate offshoring at higher degrees (due to lower intra-firm agency and transaction costs), thereby enlarging the range for which R & D offshoring can be effectively implemented (through captive rather than contract offshoring), an extreme degree of captive offshoring is likely to hurt firms' innovative performance. Consequently, we argue that while captive offshoring allows firms to expand their offshoring beyond the scale that is manageable by contract offshoring, excessive offshoring still needs to be avoided.

Hypothesis 2. The decline in innovation performance due to excessive offshoring shows up for contract offshoring at a lower degree than for captive offshoring, such that the optimum level of contract offshoring is lower than that of captive offshoring.

2.3. Requiring a minimum scale for effective captive offshoring

The advantage of captive over contract offshoring at higher offshoring degrees does not come without disadvantages. Even at very low degrees, contract offshoring enables firms to benefit from the expertise of specialized contract partners that are well embedded in the foreign innovation network (Johanson and Vahlne, 2009). Furthermore, even if firms' offshoring activities do not reach a sufficient scale, economies of scale can still be realized via contracting with larger (foreign) partners (e.g., Berchicci, 2013). In contrast to contract offshoring, we argue that captive offshoring requires a certain minimum threshold to display advantageous effects on firms' innovation performance.

First, firms conducting captive offshoring face specific costs. Even at low degrees of captive offshoring, firms are likely to face high costs for machinery, laboratories, staffing, and internal management systems, which may not be working to full capacity (Lu and Beamish, 2004). On top of forgoing economies of scale at the foreign site, which larger foreign contract partners might realize, captive offshoring also hampers the economies of scale and scope that a firm could realize in a domestic and centralized innovation system (Belderbos et al., 2013; De Meyer, 1991; Fisch, 2003; Mudambi, 2008; Pearce, 1999).

Second, and reinforcing the effect of high start-up and fixed costs associated with captive offshoring, foreign R & D sites experience additional scale and scope economies due to lateral spillovers and agglomeration economies at the micro level (Kuemmerle, 1998). Offshore R & D sites are found to be more successful once achieving a minimum scale that enables spillovers between different R & D teams, both in the directed search for solutions as well as the accidental spillovers due to informal communication.

Third, embedding an R & D site in the foreign innovation and business network requires substantial managerial engagement and financial assets. Through captive offshoring, a firm may incur costs that a foreign firm already embedded in a business network of relationships and contacts does not face (Johanson and Vahlne, 2009; Schmidt and Sofka, 2009). Especially at low degrees of captive offshoring, an own foreign R & D site might not be fully integrated into the foreign innovation network, meaning that communication and exchange within the foreign network is less effective. Moreover, firms with low connectedness in the foreign location provide less knowledge inputs to the parent company (Nobel and Birkinshaw, 1998) and MNE's subsidiaries in a foreign market may not gain access to the host country's knowledge as efficiently as local competitors (Schmidt and Sofka, 2009).

In sum, captive offshoring might be disadvantageous at small degrees of offshoring. Only after a sufficient degree (minimum threshold) is reached, captive offshoring may start providing net benefits.

Hypothesis 3. *At low degrees of captive offshoring, firm innovation performance decreases with captive offshoring up to a threshold after which innovation performance increases.*

2.4. R & D intensity, offshoring strategies and innovation performance

The acquisition, transfer, and commercialization of foreign knowledge is central in reaping the benefits of both contract and captive offshoring R & D. In order to efficiently source available knowledge and technologies in foreign countries through R & D offshoring and its utilization, firms need a certain degree of overlap of their existing knowledge stock with the new and possibly foreign knowledge (Van Wijk et al., 2008; Yang et al., 2008). A firm's ability to evaluate, internalize, and commercialize knowledge is not only important with respect to inter-organizational knowledge sources (Cohen and

Levinthal, 1990; Escribano et al., 2009; Mowery et al., 1996), but also for intra-organizational sources (Gupta and Govindarajan, 2000; Szulanski, 1996). Knowledge transfer within firm boundaries, but across different sites and countries, may, for instance, be hindered by geographic and cultural distance (Ambos and Ambos, 2009; Markides and Berg, 1988; Shenkar, 2001). Firms' managerial and financial commitment to R & D at home and abroad may, hence, facilitate a more efficient transfer and exploitation of both external and foreign knowledge.

A firm's R & D intensity (total R & D investment over firm's total sales) can be seen as an indicator of how intensively it invests in building and maintaining its knowledge stock (cf., Cohen and Levinthal, 1990). Moreover, when managers place high emphasis on innovation (as indicated by high R & D intensity), they may be more likely to install internal processes that enable and leverage the transfer and commercialization of foreign knowledge. Thus, firms with high R & D intensities might be more able to exploit foreign knowledge. For knowledge sourcing through outsourcing, there is a positive moderation effect of a firm's knowledge stock (Berchicci, 2013; Grimpe and Kaiser, 2010). For knowledge sourcing through offshoring, such a positive moderating effect is theoretically suggested with respect to the relationship between contract offshoring and innovation performance (Martínez-Noya et al., 2012; Mihalache et al., 2012). According to our previous discussion, we suggest that the mechanism leveraging the internalization and transfer of knowledge also affects the intra-firm transfer and application of knowledge across countries.

Independent of whether offshoring is implemented through contract offshoring or through captive offshoring, the ability to benefit from knowledge transfer and, thus, the returns to offshoring, will be larger for firms with higher R & D intensity. These higher returns, due to a positive moderation, have two implications. On the one hand, these firms are able to achieve higher degrees of offshoring before the negative effects of offshoring become dominant, that is, the tipping point shifts to the right (Grimpe and Kaiser, 2010). This shift is also combined with a higher performance at the tipping point, that is, an upward shift. On the other hand, the negative effects of increasing captive offshoring at low scales are more easily balanced by the higher benefits of offshoring. Hence, the threshold needed to achieve positive returns to captive offshoring shifts toward lower degrees of captive offshoring, that is, a shift to the left. The following hypotheses summarize our discussion.

Hypothesis 4a. R & D intensity positively moderates the relationship between contract offshoring and innovation performance, such that the decline in innovation performance due to excessive contract offshoring shows up with higher degrees of contract offshoring.

Hypothesis 4b. R & D intensity positively moderates the relationship between captive offshoring and innovation performance, such that the decline in innovation performance due to excessive captive offshoring shows up with higher degrees and the threshold for observing a positive effect on innovation performance shows up with lower degrees of captive offshoring.

3. Data and methods

3.1. Sample

We test our hypotheses using a longitudinal R & D dataset provided by the *Wissenschaftsstatistik* of the *Stifterverband für deutsche Wissenschaften (SV data)* in combination with the *Dafne* database by Bureau van Dijk, which comprises annual accounts for German companies. The SV data provide detailed information on firm's employees, sales, R & D personnel, as well as internal and external R & D expenditures, which allows for differentiating between R & D expenditures on foreign external parties (contract offshoring) and on foreign affiliates (captive offshoring). The underlying definitions of R & D indicators in the SV data follow internationally standardized rules that are set in the Frascati Manual (OECD, 2002). In order to control for firm age, industry, and regional effects, we combined the SV data with the Dafne database, which contains the required information, but lacks detailed information on R & D expenditures. The longitudinal set up of both the SV data and the Dafne data allow us to construct a firm-level panel.

The SV data are based on an R & D survey that is conducted in Germany, including all enterprises and cooperative research entities presumed to be active in R & D. The survey is conducted biannually on behalf of the *German Federal Ministry of Education and Research* and is part of the official reporting on Germany's research and development to the EU and the OECD. Our final sample comprises 7730 data points from 2421 German firms with domestic or foreign R & D activities for 2005, 2007, 2009, and 2011. Comparing the variable total sales from the SV data with the corresponding variable from the Dafne database, which is based on financial data from official tax reporting, we observe a very good fit between both datasets ($r = 0.84$). The SV data are already used in research on R & D spending (e.g., Engel et al., 2016; Schmid et al., 2014). Schmid and colleagues particularly emphasize a specific advantage of the SV data, namely that it suffers less from strategic considerations regarding external accounting policy, like R & D smoothing and under-reporting of R & D expenditure in financial tax reports.

3.2. Variables

3.2.1. Dependent variable

Following established practice in innovation studies (e.g., Berchicci, 2013; Cassiman and Veugelers, 2006; Mihalache et al., 2012), we measure a firm's *innovation performance* by the share of its sales from new or significantly improved products over its total sales in the domestic market. We derive this variable from the SV data.[4] It is a continuous variable ranging from 0 to 100.

3.2.2. Focus variables

Following similar practices for quantification of outsourcing (e.g., Grimpe and Kaiser, 2010) and offshoring activities (Mihalache et al., 2012), we measure *contract offshoring R & D* by a firm's spending on R & D services from external foreign parties, divided by the firm's total R & D spending. Contract offshoring R & D is a continuous variable ranging from 0 (i.e., the activity is not performed at foreign locations via external parties at all) to 1 (i.e., the activity is fully performed at foreign locations via external parties).

We measure *captive offshoring R & D* by a firm's spending on R & D services from affiliates in a foreign country, divided by the firm's total R & D spending. Captive offshoring R & D is a continuous variable ranging from 0 (i.e., the activity is not performed at foreign locations via affiliated companies at all) to 1 (i.e., the activity is fully performed at foreign locations via affiliated companies).

Following Cohen and Levinthal (1990), we operationalize *R & D intensity* using firm's total R & D spending divided by total sales. The variable is continuous, taking values from 0 to 40.

3.2.3. Control variables

As the degree of R & D contract offshoring could also be related to the balance of internal and external research in the domestic domain, which affects innovation performance independent of R & D offshoring (Cassiman and Veugelers, 2006), we control for the degree of *internal*

[4] For example, in the 2011 SV survey wave respondents are asked to give the turnover shares of new products and respectively improved products to the firm that have been introduced since 2009. The measurement for innovation performance is also equivalent to the corresponding questions in the well-known Community Innovation Survey (CIS) survey.

domestic R & D spending, i.e., a variable ranging from 0 to 1, calculated as a firm's internal domestic R & D spending over total R & D spending. In addition to this relative share, we also include the number of *domestic R & D employees* (per thousand) to approximate the size of the R & D department at home.

The ownership structure influences firms' internationalization strategy (Fernández and Nieto, 2006). Specifically, firms' internationalization activities are affected by being part of a larger corporate network or a group of affiliated companies (e.g., Engel et al., 2013). To control for these effects, we include *group* as a dichotomous control variable, taking the value 1 if the firm is part of a larger corporate network and 0 otherwise. Furthermore, firms with foreign ownership are more likely to become internationally engaged (e.g., Greenaway et al., 2007). Therefore, we include *foreign* as a dichotomous control variable, taking the value 1 if the firm has a foreign owner and 0 otherwise.

Following previous studies, we include additional firm-specific control variables that are possibly related to innovation output (e.g., Belderbos et al., 2004; Massini et al., 2010). *Age* is a continuous variable capturing the firm's age at its natural logarithm. The *size* of the company is measured by the natural logarithm of the number of employees.

To control for any remaining industry or time effects we include *industry* dummies categorized on basis of aggregated two-digit NACE Rev.2 codes (Engel et al., 2013) and survey-wave *year* dummies.

3.3. Analytical methods

To examine the relationship between a firm's innovation performance with contract offshoring and captive offshoring, respectively, we estimate a Tobit model (Berchicci, 2013; Bertrand and Mol, 2013). Standard errors are clustered at the firm level to account for the correlation between repeated observations of the same firm. While the Pseudo-R-squared based on McFadden cannot be interpreted like R-squared in OLS regression analysis and is generally less suited for tobit models (Veall and Zimmermann, 1994), we report it to demonstrate that we are in ranges comparable with previous research (e.g., Berchicci, 2013). As R & D effort might require some time before having an impact on firm innovation output (e.g., Belderbos et al., 2004), we lag all independent and control variables related to innovation input by two years (e.g., Bertrand and Mol, 2013), which is equivalent to one SV data wave. We test our Hypotheses 1a, 1b, 2 and 3 by including linear and squared effects of contract offshoring R & D and linear, squared, and cubic effects of contract offshoring. To test Hypotheses 4a and 4b we interact the linear term of contract offshoring R & D, respectively captive offshoring R & D with R & D intensity (cf., Berchicci, 2013; Grimpe and Kaiser, 2010). To ensure the robustness of our findings, we apply a set of different estimation and test procedures, including, for example, a random effects Tobit model to better account for the panel setting and a pooled OLS model with an industry-standardized dependent variable to account for between-industry variations in mean and variance of innovation performances.

4. Results

In our sample, the shares of firms conducting captive offshoring and contract offshoring are relatively large, at 34 percent and 35 percent, respectively.[5] Table 1 reports the descriptive statistics for the variables used in our regression analyses for all firms (Table 2 reports the related correlations), for firms that engage in R & D offshoring, and for those that do not engage in R & D offshoring. Observing that firms conducting either of the offshoring strategies spend 1.6 per cent of their R & D expenditures on contract offshoring is fairly consistent with related figures for R & D outsourcing of German firms from the Community Innovation Survey (CIS) (Grimpe and Kaiser, 2010). Additional subsample analyses revealed that firms engaging in contract offshoring R & D invest on average 1.7 percent in this activity, but firms engaging in captive offshoring invest 3.6 percent in this type of offshoring; that is, when engaging in captive offshoring, on average it is to a higher degree. Furthermore, as can be seen from the positive correlation of both strategies (Table 2), firms engaging in one strategy also tend to engage more strongly in the other strategy.

Table 1
Descriptive statistics.

	Variables	All firms		Engaged in offshoring R & D		Not engaged in offshoring R & D	
		N = 3365		N = 996		N = 2369	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
1	Innovation performance	48.343	28.881	48.581	29.262	48.243	28.725
2	Size (ln)	4.459	1.641	4.893	1.770	4.277	1.549
3	Age (ln)	3.348	0.788	3.379	0.810	3.335	0.778
4	Group	0.379	0.485	0.490	0.500	0.333	0.471
5	Foreign	0.169	0.375	0.216	0.412	0.149	0.356
6	Domestic R & D employees	0.041	0.254	0.075	0.294	0.026	0.233
7	Internal domestic R & D	0.897	0.174	0.791	0.205	0.942	0.136
8	R & D intensity (RDI)	0.150	0.849	0.155	0.797	0.147	0.870
9	Contract offshoring R & D	0.005	0.023	0.016	0.040	0.000	0.000
10	Captive offshoring R & D	0.010	0.042	0.033	0.073	0.000	0.000

Table 3 reports our main regression analyses. To reduce potential multicollinearity of interaction terms, we standardized those independent variables that enter interaction terms (cf., Cohen et al., 2013). Small to moderate correlations between the variables (see Table 2) and variance inflation factors between all main and bilateral interaction and squared effects below 6.0 do not indicate problems with multicollinearity (O'Brien, 2007). Including the cubic effects increases these values, but as the higher correlations occur only between the cubic effects and lower order effects of the same variable, it has no adverse consequences. Model 1 estimates the relationship between firms' innovation performance and the control variables including the main effect of R & D intensity. Firm age negatively affects innovation performance,[6] while firm size and ownership characteristics are not statistically significant. Estimated coefficients of internal domestic R & D and domestic R & D employees are positive and statistically significant. The same holds for R & D intensity.

Model 2 additionally includes all explanatory variables needed to test Hypotheses 1, 2, and 3. The coefficients of both the linear and the squared term for contract offshoring R & D are statistically significant in the expected directions. The relationship between contract offshoring and innovation performance is graphically illustrated in the left part of

[5] Concerning domestic R & D activities, we observe that 99 percent of the firms conduct some domestic in-house R & D and 53 percent engage in domestic outsourcing through contracting R & D.

[6] While the negative effect hints at an innovation advantage for younger firms, an alternative explanation might be that younger firms have a higher share of new product sales because they have been in the market for a shorter period of time and, consequently, sales generated through mature products are not as high. We compared means for our dependent variable for young firms (age equal or less than 10 years) with older firms (age >10 years). There is no statistically significant difference between the two with $p = 0.761$ in a two-sided *t*-test. Therefore, the effect we find seems to hint at an innovation advantage that is not driven by very young firms.

Table 2
Correlations.

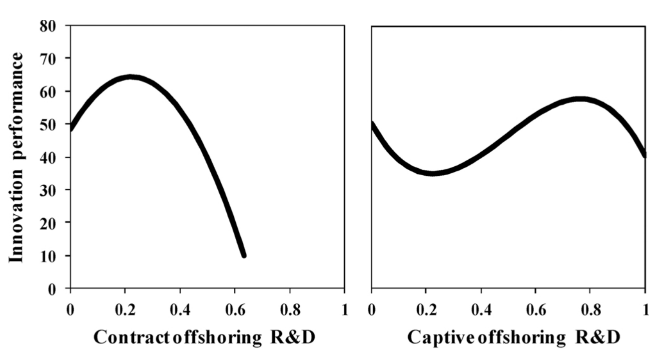
	Variables	1	2	3	4	5	6	7	8	9	10
1	Innovation performance	1									
2	Size (ln)	−0.08***	1								
3	Age (ln)	−0.10***	0.45***	1							
4	Group	−0.05***	0.53***	0.16***	1						
5	Foreign	−0.04**	0.25***	0.04**	0.48***	1					
6	Domestic R & D employees	0.04**	0.33***	0.10***	0.12***	0.01	1				
7	Internal domestic R & D	0.06***	−0.04***	−0.01	−0.05***	−0.05***	−0.05*	1			
8	R & D intensity (RDI)	0.11***	−0.12***	−0.11***	−0.02	0.03*	0.00	0.015	1		
9	Contract offshoring R & D	0.01	0.00	−0.02	0.02	0.06***	0.04**	−0.36***	0.02	1	
10	Captive offshoring R & D	−0.05***	0.07***	0.00	0.09***	0.09***	0.07***	−0.44***	0.00	0.23***	1

Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3
The effects of R & D offshoring strategies and R & D intensity on innovation performance.

	Model 1		Model 2		Model 3		Model 4	
	Tobit Only control variables		Tobit Base model		Tobit Base model with moderation by R & D intensity		Ordinary least squares Innovation performance standardized within industries	
Size	−0.18	(0.52)	−0.13	(0.53)	−0.14	(0.52)	−0.01	(0.02)
Age	−3.19***	(0.87)	−3.26***	(0.87)	−3.20***	(0.87)	−0.12***	(0.03)
Group	−0.44	(1.55)	−0.32	(1.55)	−0.30	(1.55)	−0.02	(0.05)
Foreign	−1.30	(1.83)	−1.20	(1.83)	−1.21	(1.83)	−0.05	(0.06)
Domestic R & D employees	7.54**	(3.23)	8.08***	(3.06)	7.17**	(3.00)	0.22***	(0.07)
Internal domestic R & D	7.20**	(2.94)	3.91	(3.64)	3.01	(3.64)	0.13	(0.12)
R & D intensity (RDI)	15.78***	(4.41)	15.76***	(4.44)	16.07***	(4.10)	0.12***	(0.03)
Contract offshoring R & D			3.21***	(1.08)	2.49**	(1.08)	0.09***	(0.03)
Contract offshoring R & D squared			−0.17***	(0.06)	−0.14**	(0.07)	−0.00***	(0.00)
Captive offshoring R & D			−6.12***	(1.67)	−5.63***	(1.65)	−0.19***	(0.06)
Captive offshoring R & D squared			0.77***	(0.27)	0.65**	(0.26)	0.02***	(0.01)
Captive offshoring R & D cubic			−0.02**	(0.01)	−0.02**	(0.01)	−0.00**	(0.00)
Contract offshoring R & D × RDI					3.62**	(1.75)	0.02	(0.01)
Captive offshoring R & D × RDI					3.26**	(1.51)	0.22***	(0.06)
Year	Yes		Yes		Yes		Yes	
Industry	Yes		Yes		Yes		Yes	
Constant	46.32***	(4.10)	48.81***	(4.42)	49.45***	(4.43)	0.06	(0.15)
Left-censored/Right-censored	21/198		21/198		21/198			
Sigma	28.74***	(0.37)	28.65***	(0.37)	28.61***	(0.37)		
Pseudo R^2/R^2 (for Model 4)	0.0142		0.0148		0.0151		0.0807	
N (clusters)	3365	(2241)	3365	(2241)	3365	(2241)	3365	(2241)

Notes: Dependent variable: Innovation performance; standard errors in parentheses.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.



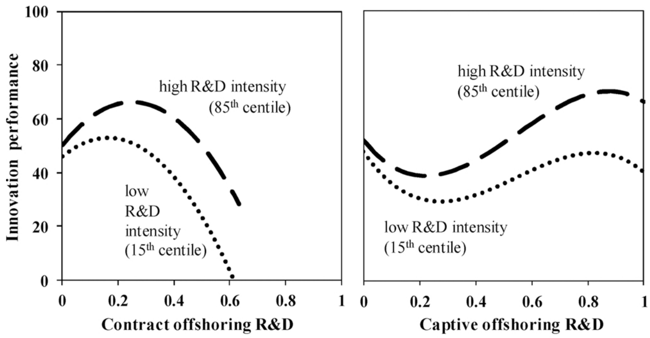
Note: Plots based on Model 2.

Fig. 1. The relationship between both R & D offshoring strategies and innovation performance.

Fig. 1. Supporting Hypothesis 1a, contract offshoring R & D positively affects innovation performance up to an intermediate point; beyond this point, contract offshoring R & D negatively affects innovation performance (i.e., displaying an inverse-U-shaped relationship).

The coefficients related to captive offshoring R & D indicate a statistically significant cubic effect,[7] which is illustrated graphically in the right part of Fig. 1. Firms engaged in captive offshoring face a reduction in their innovation performance up to a certain threshold. Beyond this threshold more captive offshoring positively affects innovation performance and reaches levels that are above the performance level of firms without captive offshoring. However, the positive effect is decreasing and, beyond a critical level, it turns negative such that innovation performance decreases. These findings support Hypotheses 1b (the decline in innovation performance for excessively high degrees of captive offshoring) and 3 (the decline in innovation performance for very low degrees of captive offshoring, which turns into positive effects after a critical threshold). In support of Hypothesis 2, we observe that the optimal degree of captive offshoring is significantly larger than the optimal degree of contract offshoring, i.e., the performance-maximizing

[7] Please note, although we did not theorize a cubic effect for contract offshoring R & D. However, including a cubic effect of contract offshoring does not change our conclusions regarding the hypothesized inverse U-shaped relationship between contract offshoring R & D and innovation performance. Results are available upon request.



Note: Plots based on Model 3.

Fig. 2. The moderating effect of R & D intensity on the relationship between contract offshoring R & D, respectively captive offshoring R & D, and innovation performance.

threshold is further to the right in Fig. 1 (delta = 0.535, S.E. = 0.057, p < 0.000).

To test Hypotheses 4a and 4b, Model 3 additionally includes interaction terms of contract offshoring R & D, respectively captive offshoring R & D, with R & D intensity (see Berchicci, 2013; Grimpe and Kaiser, 2010). Both captive offshoring and contract offshoring are statistically significantly and positively moderated by R & D intensity. As illustrated in Fig. 2, which plots the relationships for low and high levels of R & D intensity (15th and 85th centile, respectively), the performance maximizing degrees of offshoring are shifted to the right, i.e., to higher degrees of offshoring, for both captive offshoring and contract offshoring. Furthermore, the threshold beyond which expanding captive offshoring has a positive effect on innovation performance shifts to the left, i.e. to lower degrees of captive offshoring. These results support our Hypotheses 4a and 4b.

We perform several robustness checks to further explore our findings. First, differences in the mean and variance of firms' innovation performance across different sectors may influence our results. Stronger variation in innovation performance may be fairly common in some industries (e.g., information and communication technologies), while it might be rather unusual in other industry sectors (e.g., construction). To account for such heterogeneity, we take out between-industry variation in means and standard deviations of innovation performance by standardizing the innovation performance within each of the industrial sectors (two-digit NACE Rev.2 codes, see Eurostat, 2008; Engel et al., 2013). Due to the resulting heterogeneity of lower and upper limits across different industries, a Tobit model with fixed upper and lower thresholds is not suitable when using the within-industry standardized innovation performance. Hence, we fall back to an ordinary least squares regression analysis (see Table 3, Model 4). While all effects remain robust, only the moderation of contract offshoring by R & D intensity is not statistically significant.

We further explore the role of industry-level contingencies on the effects of both offshoring strategies on innovation performance (see Table 4). We focus on three characteristics potentially related to our conceptual arguments as to why the effect of captive offshoring on innovation performance differ from related effects of contract offshoring, namely, demand uncertainty, asset-specificity, and exploitation or exploration as dominant motive for R & D internationalization. We additionally explore if a firm's relative technological position within its industry, i.e., being among the leading or lagging firms, affects our findings, highlighting under which contingency firms are more likely to benefit from both offshoring strategies.[8] Data for these additional analyses are drawn from the *Mannheimer Innovationspanel* (MIP), which is the German part of the European Union's Community Innovation Survey and is based on stratified random sampling of the population of all domestic firms (cf., Grimpe and Sofka, 2016), and the *Stifterverband FuE Datenreport* (cf., Kladroba, 2011, 2013). For each of the three characteristics, we estimate three separate models (Model 5–7 in Table 4). Within each model, we created two dummy variables, one for the group of industries scoring above the median (high) and another for the group of industries scoring below the median (low) with respect to a given characteristic. We include the dummy for the first group (above median) in the regression analyses to account for the simple difference in innovation performance between the two groups of industries (i.e., the main effect). We further include the product terms of all key variables with both the dummy for the group above the median and the dummy for the group below the median. Table 4 illustrates this by reporting two blocks of estimations for our key variables. These two blocks reflect the coefficients of the offshoring variables estimated for each of the two groups of the industry split. Based on Table 4, Fig. 3 graphically illustrates the estimated effects.

Due to having fewer firms in subgroups, we face more restrictions for observed levels of captive and contract offshoring. The number of observations, especially for higher levels of offshoring, is considerably reduced, so that it is difficult to achieve sufficient power in statistical tests (cf., Haans et al., 2016; Jiang et al., 2011; Laursen and Salter, 2006). As depicted in Fig. 3, we occasionally observe strict range restrictions in the levels of captive offshoring, such that we cannot identify a potential decline for excessive captive offshoring, that is, the cubic effect, for firms in these subsamples. Furthermore, the correlation between the linear, squared, and cubic effects might make significance tests of the linear and squared effect less informative; hence, we indicate in Table 4 (see related notes in the table) if linear or squared effects are statistically significant when excluding the higher-order effects or when joint significance tests indicate an effect. In sum and despite a substantial heterogeneity between industries, we find that the general relationship of contract offshoring (inverse U-shape) and captive offshoring (S-shape, respectively the U-shape for lower levels) with innovation performance remains rather stable for all four panels in Fig. 3.

First, to investigate the role of *demand uncertainty* within industries, we build on the assumption that in industries characterized by high volatility in innovation performance, firms are exposed to higher, rather than lower, levels of uncertainty, e.g., regarding the prediction of product sales (Klingebiel and Rammer, 2011). Building on the MIP (2005–2014), we calculate the inter-temporal variance of the share of sales from new or significantly improved products aggregated over all firms within each industry. Fig. 3B (based on Model 5) reveals that the decrease in innovation performance due to excessive contract offshoring is strongest under high uncertainty, while captive offshoring seems to be an efficient strategy to deal with (transaction) costs related to uncertainty. This is in line with Williamson (1985), who states that under demand uncertainty, transaction costs are best dealt with through an internal governance mode.

Second, to explore the role of *asset-specificity* of a firm's innovation system, we assume that less asset-specific innovation systems are associated with higher technological diversification (cf., Nakamura and Odagiri, 2005; Pisano 1990; Stanko and Calantone, 2011) and that this diversification can be measured as the spread of an industry's investments across different technology fields (cf., Belderbos et al., 2013). Based on data from the *Stifterverband FuE Datenreport* (cf., Kladroba, 2011, 2013), asset-specificity is calculated for the most fine-grained industry categorization provided by the *Stifterverband FuE Datenreport* with 26 industry groups, as the Herfindahl index of investments across the available twelve technology fields. Transaction costs economics would suggest that in industries with higher asset-specificity, it might be more beneficial for firms to opt for an internal implementation compared to industries with lower asset-specificity (cf., Stanko and Calantone, 2011). In our data (Fig. 3B based on Model 6), we do not observe that the optimal degrees of captive and contract offshoring

[8] We thank two anonymous reviewers for pointing us to the insightful analyses reported in Table 4.

Table 4
Subgroup analyses for demand uncertainty, asset specificity, relative importance of exploitation for internationalization and relative technological position.

Industry split	Model 5 Tobit Demand uncertainty		Model 6 Tobit Asset specificity		Model 7 Tobit Exploitation motive		Model 8 Tobit Technological position	
Subgroup-specific effect (high)	High uncertainty		High asset specificity		More exploitative		Leading firms	
R & D intensity (RDI)	14.53***	(4.21)	20.59***	(6.24)	33.25***	(7.08)	10.69***	(3.47)
Contract offshoring R & D	4.47**	(1.93)	6.40**	(2.70)	1.91	(2.97)	6.15***	(2.33)
Contract offshoring R & D squared	−0.35***	(0.13)	−0.42***	(0.16)	−0.17	(0.19)	−0.38**	(0.15)
Captive offshoring R & D	−5.68**	(2.74)	−8.03***	(2.76)	−6.50**	(2.79)	−10.56**	(4.70)
Captive offshoring R & D squared	0.74 [a,b)]	(0.59)	1.10***	(0.40)	0.60 [a,b)]	(0.56)	2.27* [a,b)]	(1.41)
Captive offshoring R & D cubic	−0.02 [a)]	(0.03)	−0.03**	(0.01)	−0.01 [a)]	(0.03)	−0.11[a)]	(0.10)
Contract offshoring R & D × RDI	4.90**	(1.92)	13.12**	(5.12)	−2.71	(6.30)		
Captive offshoring R & D × RDI	1.05	(1.66)	6.06	(4.02)	−1.49	(3.65)		
Subgroup-specific effect (low)	Low uncertainty		Low asset specificity		Less exploitative		Lagging firms	
R & D intensity (RDI)	20.38***	(5.82)	15.64***	(5.61)	13.03***	(3.69)	37.51***	(8.18)
Contract offshoring R & D	2.68 [c)]	(1.63)	2.67	(2.26)	2.45*	(1.36)	1.95*	(1.12)
Contract offshoring R & D squared	−0.08 [c)]	(0.05)	−0.22	(0.17)	−0.11*	(0.06)	−0.11**	(0.05)
Captive offshoring R & D	−6.35***	(2.17)	−7.47**	(3.63)	−4.18*	(2.49)	−5.05***	(1.71)
Captive offshoring R & D squared	0.73**	(0.32)	0.78 [a,b)]	(0.72)	0.44 [a,b)]	(0.49)	0.49* [a,b)]	(0.26)
Captive offshoring R & D cubic	−0.02*	(0.01)	−0.02 [a)]	(0.03)	−0.01[a)]	(0.02)	−0.01 [a)]	(0.01)
Contract offshoring R & D × RDI	9.64	(10.56)	4.37**	(1.81)	4.08**	(2.02)		
Captive offshoring R & D × RDI	6.30**	(2.82)	1.31	(2.42)	3.62**	(1.82)		
Size	−0.03	(0.51)	0.07	(0.57)	0.16	(0.51)	0.53	(0.51)
Age	−3.10***	(0.86)	−3.79***	(0.97)	−2.74***	(0.86)	−2.93***	(0.85)
Group	−0.55	(1.55)	−1.00	(1.70)	−0.13	(1.53)	−0.26	(1.53)
Foreign	−1.27	(1.83)	−0.95	(2.03)	−1.35	(1.81)	−0.80	(1.81)
Domestic R & D employees	6.63**	(2.94)	6.50**	(2.92)	6.23**	(2.84)	4.88*	(2.93)
Internal domestic R & D	3.47	(3.66)	0.44	(4.40)	2.64	(3.62)	3.14	(3.64)
Year	Yes		Yes		Yes		Yes	
Industry	Yes		Yes		Yes		Yes	
1st group (dummy)	3.02**	(1.43)	−1.28	(1.53)	9.49***	(1.80)	4.20**	(1.77)
Constant	46.94***	(4.50)	54.43***	(5.24)	40.37***	(4.53)	46.73***	(4.45)
Left-censored/Right-censored	21/198		16/157		21/198		21/198	
Sigma	28.54***	(0.37)	28.37***	(0.41)	28.36***	(0.37)	28.41***	(0.37)
Pseudo R-squared	0.0157		0.0164		0.0170		0.0166	
N (clusters)	3365	(2241)	2728	(1963)	3365	(2241)	3365	(2241)

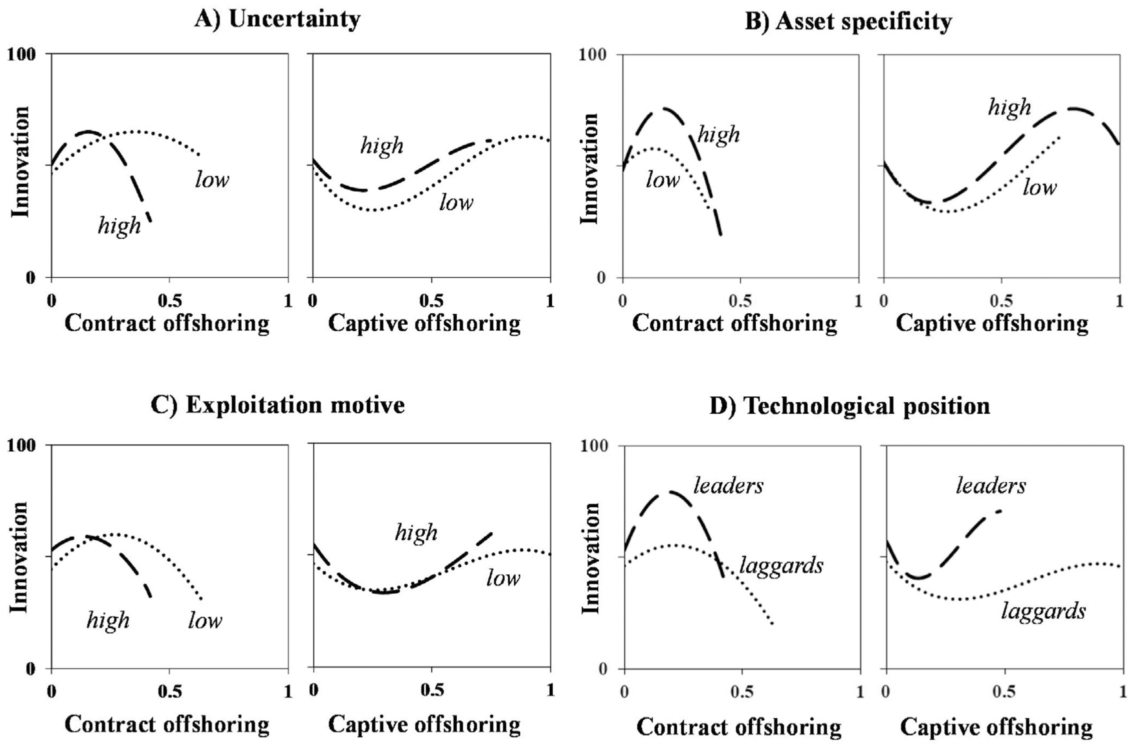
Notes: Dependent variable: Innovation performance; standard errors in parentheses. “a)” indicates a statistically significant ($p < 0.05$) joint significance test of squared and cubic effect that individually are not statistically significant at $p > 0.05$. “b)” indicates that a squared effect that is not statistically significant at $p < 0.05$ is statistically significant at $p < 0.05$ when the related cubic effect is excluded. The effects marked with “c)” are jointly significant at $p < 0.05$ when excluding the statistically insignificant cubic effect of captive offshoring and the interactions with R & D intensity.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

substantially differ between industries with high versus low asset specificity. We observe that asset specificity seems to be associated with higher benefits from both captive and contract offshoring. On the one hand, high asset specificity might, to some extent, protect innovating firms from imitators and hence make further innovations more attractive. On the other hand, asset-specificity might favor centralized R & D systems with fewer sources for innovation, which lets these firms, in turn, disproportionally benefit from knowledge sourcing from distant locations.

Third, we explore the relative importance of *exploitation* (i.e., adapting firm's innovative products to foreign markets to exploit knowledge created at home) versus *exploration* (i.e., access to new knowledge and technologies abroad to augment the domestic knowledge base) as motives for internationalizing R & D (Kuemmerle, 1999; Von Zedtwitz and Gassmann, 2002). In 2011, the MIP asked firms to assess the importance of motives for internationalizing innovation activities. Within each industry, we averaged firm-level differences between the reported relevance of exploitation and exploration motives; higher levels indicate a higher relevance of exploitation vis-á-vis exploration. Model 7 reports estimations of the related sample-split analysis and Fig. 3C visualizes the estimated effects. For captive offshoring, we do not observe substantial differences for different strengths of the exploitation motive (in the observed range available for both subgroups). For contract offshoring, firms from industries with stronger exploitation motives experience a decrease in innovation performance already at lower degrees. The risks particularly associated with contract offshoring, such as leaking knowledge (e.g., Ellram et al., 2008; Lai et al., 2009; Pisano, 1990), might be more relevant for exploitative activities, which rely more on an already rich internal knowledge base compared to explorative activities.

Last, we explore the extent to which firms being technological leaders differ from those being technological laggards. Following Grimpe and Sofka (2016), we measured technology leadership with a dummy indicating if a firm has higher than average R & D intensity (R & D expenditures relative to sales) in the corresponding NACE Rev. 2 two-digit industry and zero otherwise (cf., Grimpe and Sofka, 2016; Salomon and Jin, 2010). The results are displayed in Model 8 (Table 4). Due to the collinearity of the technological leadership measure with R & D intensity, the interaction terms with R & D intensity are not included in this model. As can be observed in Fig. 3D (based on Model 8), the observed range of offshoring, especially when conducted excessively, is much smaller for technological leaders than for laggards. The overall shape of the curves confirms results of other industry splits, even though the S-shape is much more pronounced for laggards than for leaders in the case of captive offshoring. Nevertheless, and as suggested by Cantwell and Mudambi (2011), the group of technological leaders is more likely to benefit from both offshoring strategies.

Returning to our base model with the moderation by R & D



Notes: Due to missing data, the analysis for asset specificity only relies on 88 percent of the overall sample; the observed ranges for offshoring degrees differ from the full sample.

Fig. 3. The effects of both R & D offshoring strategies depend on uncertainty, asset specificity, the relative importance of exploitation for internationalization and relative technological position.

intensity, we now proceed with five additional robustness checks (see Tables 5 and 6).[9] First, to account for potentially confounding effects caused by geographical proximity between firms and related regional knowledge-spillovers (e.g., Audretsch and Feldman, 1996), we include regional *patent applications* to our model. We merged regional official data on patent applications between 2005 and 2011 from the *German Patent and Trademark Office*. Patent applications capture the number of patent applications per one hundred thousand residents on the German state level in a given year. Normalizing patent applications by the number of residents per state reduces potentially confounding state-size effects. Due to the lack of region information for 190 observations, we cannot match corresponding regional patent information. Hence, we assign these firms the average value of all regions' patent applications (including an indicator variable for these observations does not change the conclusions). While, as could be expected, the coefficient for patent applications is positive and statistically significant, the effects of captive and contract offshoring remain robust (see Table 5, Model 9).

Second, and as a robustness check that we believe to be one of the most extreme and conservative approaches to control for industry effects and regional effects, we included dummies for the districts and all their interactions with industries and years, such that we include statistical controls for district-level industry effects and district-level industry-specific year effects. Note that this robustness check additionally takes out all variation related to region-specific industry effects and industry-specific time effects. In other words, this robustness check identifies firm-level variation within individual industries and within individual regions while at the same time allowing that regions, industries, and industries in specific regions, may evolve differently over time. Districts were classified based on the NUTS 2 (Nomenclature of Territorial Units for Statistics) codes for Germany. The 190 firms, for which we lack region information, are assigned to an additional artificial district. Industry-classifications are based on two-digit NACE codes. Despite controlling for time-dependent industry- and regional-effects, the effects of contract and captive offshoring R & D remain robust and statistically significant (see Table 5, Model 10).

Third, because captive offshoring and contract offshoring are correlated ($r = 0.23$), non-linear effects of these two strategies might merely reflect an omitted interaction effect between both strategies (Ganzach, 1997). Therefore, as a robustness check, we include the interaction of contract offshoring R & D with captive offshoring R & D. The coefficient of the interaction term is negative and statistically significant, indicating that a substitution effect may be present for both offshoring strategies (see Table 5, Model 11 and the visualization in Fig. 4). While our main findings concerning captive and contract offshoring R & D remain robust, the negative interaction seems to be in conflict with previous findings that external knowledge generation complements internal knowledge generation (e.g., Cassiman and Veugelers, 2006). In the context of offshoring, additional substitution effects may counter the complementary effects. Both contract and captive offshoring enable firms to source foreign knowledge and, therefore, are likely to be substitutes with respect to this central benefit of offshoring. In our sample, this offshoring-specific substitution effect seems to outweigh possible complementarity effects resulting from balancing internal and external forms of knowledge generation.

Fourth, we further exploit the panel characteristics of our data. We estimate a random-effects Tobit model (e.g., Belderbos et al., 2013; Grimpe and Kaiser, 2010; Grimpe and Sofka, 2016). Following Belderbos et al.

[9] As a sixth robustness check suggested by one of our reviewers, we also explored the particularities of SMEs (≤250 employees) versus larger firms. We observed effects for contract offshoring and captive offshoring for larger firms that are similar to the effects observed in our main models. For the smaller firms the effects follow the same pattern, however, we do not observe small firms with excessively large levels of offshoring activities. Results are available upon request.

Table 5
The effects of R & D offshoring strategies and R & D intensity on innovation performance (additional robustness checks).

	Model 9		Model 10		Model 11		Model 12	
	Tobit Including regional patent applications as proxy for regional spillovers		Tobit Including district dummies and their interactions with industry and year dummies		Tobit Including interaction between contract and captive offshoring		Random effects tobit Base model with moderation by R & D intensity	
Size	−0.22	(0.52)	0.80	(0.59)	−0.15	(0.52)	−0.37	(0.49)
Age	−3.36***	(0.86)	−1.11	(0.96)	−3.21***	(0.87)	−3.51***	(0.85)
Group	−0.24	(1.55)	−2.80	(1.72)	−0.33	(1.55)	−0.83	(1.41)
Foreign	−1.30	(1.83)	0.08	(1.85)	−1.26	(1.83)	−0.75	(1.69)
Domestic R & D employees	7.10**	(2.95)	7.81***	(2.47)	7.15**	(3.01)	6.69**	(2.62)
Internal domestic R & D	3.10	(3.63)	3.18	(4.08)	3.10	(3.64)	0.62	(3.27)
R & D intensity (RDI)	16.23***	(4.13)	17.36***	(4.29)	16.08***	(4.05)	13.53***	(1.74)
Contract offshoring R & D	2.49**	(1.07)	2.59**	(1.18)	3.08***	(1.10)	1.36	(0.96)
Contract offshoring R & D squared	−0.14**	(0.07)	−0.18***	(0.07)	−0.16**	(0.07)	−0.04	(0.05)
Captive offshoring R & D	−5.76***	(1.64)	−5.45***	(1.82)	−5.60***	(1.63)	−4.63***	(1.38)
Captive offshoring R & D squared	0.67***	(0.26)	0.74***	(0.26)	0.74***	(0.25)	0.66***	(0.26)
Captive offshoring R & D cubic	−0.02**	(0.01)	−0.02**	(0.01)	−0.02**	(0.01)	−0.02**	(0.01)
Contract offshoring R & D × RDI	3.56**	(1.78)	6.49***	(1.33)	3.93**	(1.73)	4.72***	(1.64)
Captive offshoring R & D × RDI	3.23**	(1.54)	5.37***	(1.62)	3.75**	(1.57)	3.96**	(1.66)
Patent applications	0.03*	(0.01)						
Contract offshoring R & D × Captive offshoring R & D					−0.39***	(0.13)		
Year	Yes		Yes		Yes		Yes	
Industry	Yes		Yes		Yes		Yes	
District × industry × year dummies	No		Yes		No		No	
Constant	48.59***	(4.47)	18.87***	(6.38)	49.54***	(4.43)	53.67***	(4.12)
Left-censored/Right-censored	21/198		21/198		21/198		21/198	
Sigma/Sigma_u (for Model 11)	28.59***	(0.37)	23.04***	(0.34)	28.60***	(0.37)	23.62***	(0.54)
Sigma_e (for Model 11)							16.53***	(0.39)
Pseudo R^2/Chi^2 (for Model 11)	0.0153		0.0624		0.0152		480.52	
N (clusters)	3365	(2241)	3365	(2241)	3365	(2241)	3365	(2241)

Notes: Dependent variable: Innovation performance; standard errors in parentheses.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

(2013), we opted for a random-effects instead of a fixed-effects model for two reasons. The relatively short and unbalanced panel (the survey is not mandatory; on average, we observe each firm 2.4 times, which implies that, due to using lagged variables, the effective ratio is 1.4) makes the adoption of a fixed-effects model less advisable. Moreover, R & D offshoring strategies are unlikely to change rapidly over short periods of time. Estimating the random effects Tobit model (see Table 5, Model 12) reveals that the linear and squared effects of contract offshoring on innovation performance have the expected signs but are no longer statistically significant. However, the statistically significant interaction of the linear term of contract offshoring R & D with R & D intensity indicates that the effect of contract offshoring R & D depends on the level of R & D intensity. The linear effect is only statistically significant for higher levels of R & D intensity (for the tenth percentile: $\beta = 0.56$, S.E. = 1.05, $p = 0.590$; for the ninetieth percentile: $\beta = 2.37$, S.E. = 0.96, $p = 0.013$). Thus, conjointly considering the results of the Tobit and random-effects Tobit models, we can only support our hypotheses regarding contract offshoring for firms with high R & D intensity; conclusions regarding other hypotheses and, in particular, with respect to captive offshoring, remain unaffected.

Fifth, we further illustrate the extent to which our conclusions are independent of industry effects. Specifically, we follow an approach employed by Laursen and Salter (2014) to address industry heterogeneity. In addition to the bi-annual (for each survey wave) firm-level variables and industry fixed effects we also include bi-annual industry averages for contract offshoring R & D, captive offshoring R & D, and R & D intensity and their non-linear effects.[10] As suggested by Laursen and Salter, to facilitate the model estimation we calculate the industry averages on a more fine-grained industry specifications with 25 instead of 16 industry dummies, i.e., we expanded our industry coding by further differentiating 9 additional sectors[11] (see Table 6, Model 13). Compared to Laursen and Salter's cross-sectional data, our panel data set has the advantage that we can also estimate the model based on inter-temporal differences within industries. Hence, we could additionally include fixed effects for all industries for which we calculate the averages (see Model 14). While this latter approach implies a less efficient test for industry effects (as can be seen by less significant estimates), the estimations of the firm-level effects become more efficient. The increased efficiency is based on industry fixed effects that cover even those industry differences that are not related to industry averages of our key variables and the increased efficiency is also reflected by a substantial increase in the fit index. However, we clearly see in Models 13 and 14 (Table 6) that the coefficients for firm-level variation still reveal the same basic patterns of the relationships of contract and captive offshoring with innovation performance as our basic model, thus corroborating our previous conclusions. Overall, the analyses, as reported in Model 10 (including industry, region, time fixed effects and all their interactions), as well as Models 13 and 14, suggest that industry effects do not drive our results.

5. Discussion

The effective organization of a firm's R & D offshoring activities is central to fostering innovation output and to securing a competitive

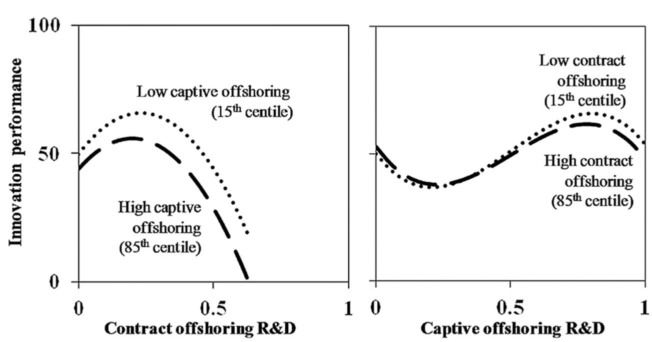
[10] While the inclusion of both industry averages and industry dummies can introduce substantial correlations between both these sets of variables, it nevertheless helps isolating firm-level effects.

[11] We further differentiated between the following manufacturing sectors: food, drink & tobacco; textiles & leather; chemicals & pharmaceuticals; manufacture of non-metallic mineral products; manufacture of metal products; electronic & electrical products; machinery, other manufacturing, and one dummy for miscellaneous manufacturing industries with less than 40 observations in our sample.

Table 6
The effects of R & D offshoring strategies and R & D intensity on innovation performance (additional robustness checks).

	Model 13		Model 14	
	Tobit Industry-level variables		Tobit Industry-level variables and additional industry fixed effects	
Size	0.24	(0.51)	0.27	(0.51)
Age	−2.96***	(0.85)	−2.65***	(0.85)
Group	−0.87	(1.53)	−0.85	(1.50)
Foreign	−1.08	(1.78)	−0.89	(1.75)
Domestic R & D employees	6.57**	(2.87)	5.78**	(2.73)
Internal domestic R & D	3.39	(3.55)	3.02	(3.56)
R & D intensity (RDI)	15.33***	(3.89)	15.25***	(3.89)
Contract offshoring R & D	2.27**	(1.06)	2.42**	(1.05)
Contract offshoring R & D squared	−0.13*	(0.07)	−0.14**	(0.07)
Captive offshoring R & D	−4.45***	(1.61)	−4.66***	(1.59)
Captive offshoring R & D squared	0.56**	(0.25)	0.60**	(0.25)
Captive offshoring R & D cubic	−0.02*	(0.01)	−0.02**	(0.01)
Contract offshoring R & D × RDI	4.11**	(1.79)	3.70**	(1.71)
Captive offshoring R & D × RDI	2.37*	(1.41)	2.22	(1.39)
Industryglevel R & D intensity (ilRDI)	5.02***	(1.05)	1.00	(1.39)
Industry-level contract offshoring R & D	2.56***	(0.97)	1.49	(1.08)
Industry-level contract offshoring R & D squared	−1.04***	(0.34)	−1.06***	(0.37)
Industry-level captive offshoring R & D	−8.85***	(1.44)	−1.65	(2.23)
Industry-level captive offshoring R & D squared	2.73***	(0.82)	1.00	(1.05)
Industry-level captive offshoring R & D cubic	−0.13**	(0.05)	−0.04	(0.06)
Industry-level contract offshoring R & D × ilRDI	1.91*	(1.14)	−1.18	(1.31)
Industry-level captive offshoring R & D × ilRDI	−2.45	(1.96)	−1.85	(2.18)
Year	Yes		Yes	
Industry	Yes		Yes (+9)	
Constant	47.85***	(4.38)	25.50	(46.46)
Left-censored/Right-censored	21/198		21/198	
Sigma	28.22***	(0.37)	27.94***	(0.37)
Pseudo R-squared	0.0180		0.0200	
N (clusters)	3365	(2241)	3365	(2241)

Notes: Dependent variable: Innovation Performance; standard errors in parentheses.
Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.



Note: Plots based on Model 11.

Fig. 4. The interaction between contract offshoring R & D and captive offshoring R & D with respect to their effects on innovation performance.

advantage. While there is some heterogeneity across industries, we observe rather robust and distinct patterns for the influence of both captive and contract offshoring of R & D on firms' innovation performance. Our study has several implications for both research and management, which are discussed below.

Previous research on aggregate measures of offshoring (pooling contract offshoring and captive offshoring, e.g., Mihalache et al., 2012) and aggregate measures of outsourcing (pooling domestic and foreign contract R & D, e.g., Berchicci, 2013; Grimpe and Kaiser, 2010) show that excessive engagement in any of these strategies is detrimental to firm innovation performance. Our analyses reveal that these effects also hold independently for captive offshoring and contract offshoring, the two most prominent strategies for R & D offshoring. We extend previous studies by demonstrating that the level beyond which innovation performance is negatively affected by more offshoring is at a substantially lower degree for contract offshoring than for captive offshoring. Thus, the question of whether R & D offshoring positively affects firm innovation performance strongly depends not only on the extent to which firms engage in R & D offshoring, but also on the chosen strategy for its implementation. Consistent with arguments put forward by Williamson (1979, 1985) on the advantages of internal over market solutions for frequent and strategically important transactions, captive offshoring as an internal implementation of offshoring seems to be more beneficial when firms intensively engage in R & D offshoring. In fact, when contract offshoring R & D amounts to about 20 percent of all firm R & D activities, contract offshoring achieves the most positive impact on innovation performance (reaching its maximum) for the average firm in our sample where captive offshoring is most disadvantageous (reaching its minimum). Similarly, the degree where captive offshoring reaches its optimum is at a level, about 70 percent for the average firm in our sample, where the disadvantages of contract offshoring already greatly outweigh the advantages from R & D offshoring. Hence, we demonstrate that these tipping (maximum) points occur at hugely different degrees depending on whether R & D offshoring is implemented internally or externally.

Captive and contract offshoring not only differ with respect to their optimal degrees, but also with respect to whether they already generate positive effects on innovation performance at lower degrees of offshoring. Our results clearly indicate that at lower and intermediate scales, captive offshoring R & D displays a U-shaped relationship with innovation performance. Thus, captive offshoring negatively affects firm innovation performance at small degrees, while the effect turns positive for intermediate degrees. This effect differs tremendously from the inverse U-shaped relationship between contract offshoring and innovation performance. The finding regarding firms with only very low degrees of captive offshoring indicates that at low degrees of R & D offshoring, the substantial costs involved in developing specialized internal governance structures are not likely to be recovered by the benefits (Calantone and Stanko, 2007; Williamson, 1991). Consequently, in this case there are strong incentives to outsource offshored R & D activities to contract partners.

Considering our contributions discussed above, future research on offshoring should acknowledge the highly non-linear and distinct nature of the relationships between contract respectively captive offshoring with firm innovation performance. Not accounting for these nonlinearities (e.g., Rodríguez and Nieto, 2016) might substantially bias conclusions, as we cannot generalize findings from larger rather highly internationalized MNEs to smaller less internationalized firms and vice versa. While SMEs might be well advised to conduct contract offshoring R & D to tap into foreign knowledge without high initial upfront costs, highly internationalized MNEs might rather opt for the more expensive international implementation to reap the full benefits from offshoring R & D. One advantage of our study is that it is based on a large and representative sample of R & D active firms with various degrees of offshoring and R & D intensities.

Furthermore, the identification of potentially negative effects of offshoring may suffer from observing insufficient numbers of firms excessively engaged in captive and contract offshoring (see similar discussion by Grimpe and Kaiser, 2010, for the case of outsourcing, and Laursen and Salter, 2006, for the case of knowledge search, and Haans et al., 2016, for a general discussion). Firms with excessive offshoring may recognize that they went beyond the optimal degree of offshoring, then subsequently re-shore and divest in order to return to an optimal level (e.g., Ellram et al., 2013). We observe such cases for selected subsamples, for instance, for firms in industries that are uncertain and dominated by exploitation as motive for R & D internationalization. Thus, when future research focuses on smaller or particular subsamples, the analyses might not be powerful enough to identify all parts of the non-linear relationship.

Beyond our basic insights on the nonlinear effects of contract and, in particular, of captive offshoring R & D, our empirical findings also stress a central role for R & D intensity in efficiently utilizing the potential benefits of R & D offshoring. As previously theorized in the offshoring literature (e.g., Martínez-Noya et al., 2012; Mihalache et al., 2012) and demonstrated in a comparable context of domestic outsourcing (Berchicci, 2013; Grimpe and Kaiser, 2010), we empirically demonstrate that intensive investments in a firm's knowledge stock is highly relevant for utilizing foreign external knowledge accessed through contract offshoring. Consistent with Van Wijk et al. (2008), who state that absorptive capacity also positively affects intra-organizational knowledge transfer, we demonstrate a positive and statistically significant moderation effect for captive offshoring. This illustrates that even keeping offshored R & D activities inside firm boundaries does not fully mitigate cross-border barriers to transfer and commercialize knowledge. Therefore, future research should take into account that R & D intensity is an important moderator when analyzing the performance impact of R & D offshoring not only for externally offshored but also for internally offshored R & D.

Our study focuses on two prominent offshoring strategies, i.e., contract offshoring as a market-based offshoring strategy and captive offshoring as an internal offshoring strategy, but hybrid offshoring strategies that incorporate elements of both market-based and internal strategies (Williamson, 1991) might also be relevant in the context of offshoring R & D (Sartor and Beamish, 2014). Due to data constraints, however, we cannot analyze such hybrid forms in this study. Future studies that are able to identify hybrid forms of R & D offshoring, along with contract offshoring and captive offshoring, could build on our theoretical and empirical findings to develop models that include a more fine-grained distinction of offshoring strategies. We may expect that such intermediate forms reach their optimal degrees somewhere between the optimal degrees of contract and captive offshoring.

Regarding our analysis of captive and contract offshoring, we face two additional limitations. First, the mandate in terms of exploration (competence-creating) versus exploitation (competence-exploitation) of each offshored R & D activity on the subsidiary or contract level is likely to have an influence on the offshoring-performance relationship (cf., Birkinshaw and Hood, 1998; Cantwell and Mudambi, 2005; Sofka et al., 2014). Unfortunately, we do not have information on the mandates at the subsidiary or project level. To at least partially address this issue and, thereby, going beyond previous related research (e.g., Mihalache et al., 2012; Nieto and Rodríguez, 2011; Rodríguez and Nieto, 2016), we exploit information on between-industry variation regarding the relevance of exploitation versus exploration motives for R & D offshoring. Second, while we focus on the degree of offshoring in terms of both contract and captive offshoring, we cannot investigate differences between firms that have more dispersed or more concentrated offshored activities; for example, in terms of the number, size, and location of their foreign R & D sites respectively contract partners. This choice between dispersed and concentrated organization, for instance, might substantially influence firms' innovation performance (cf., Porter, 1986). Future research gaining access to more comprehensive data might be able to more thoroughly investigate these issues.

Our rather robust findings regarding the basic patterns of the relationship between the different strategies for R & D offshoring and innovation performance offer some tentative managerial advice. Both R & D offshoring strategies offer opportunities to enhance innovative output. The actual realization of such benefits and, thus, the optimal engagement in R & D offshoring depends on the chosen strategy. When firms find suitable foreign partners, contract offshoring offers firms the possibility to benefit from foreign sources of knowledge even at relatively low internationalization degrees. However, managers should be aware that excessive contract offshoring increases the threat of information leakage and cannibalizes internal capabilities that are needed to efficiently absorb external foreign knowledge. When higher degrees of offshoring are set to be implemented, managers should seriously consider captive offshoring as the preferred strategy, because it allows achieving optimal offshoring at much higher degrees than contract offshoring. However, when firms decide to conduct R & D offshoring via captive offshoring, they need to overcome potentially high set-up costs before benefiting from economies of scale at the foreign location. High commitment, in terms of a sufficiently large engagement in foreign R & D, seems to be necessary in order to reap the full benefits of captive offshoring. Still, extremely high levels of R & D offshoring should be avoided. For both strategies of R & D offshoring, firms need to build and maintain a knowledge stock, reflected, e.g., by a high R & D intensity, that can help to better absorb knowledge gained through foreign R & D activities.

6. Conclusion

In this paper, we analyze the R & D offshoring-performance relationship by explicitly differentiating between contract offshoring and captive offshoring. Contract offshoring, as an external offshoring strategy, allows firms to obtain positive innovation returns at low degrees of offshoring, but becomes disadvantageous at intermediate and higher degrees. In contrast, and consistent with Williamson (1979, 1985), we observe that captive offshoring as an internal implementation of offshoring is particularly beneficial for higher degrees of offshoring, where contract offshoring is no longer effective due to relatively high transaction costs. Hence, captive offshoring allows firms to expand the range of beneficial offshoring. Nevertheless, captive offshoring also decreases firms' innovation performance when excessively employed; compared to contract offshoring, the tipping point, however, is at much higher degrees. Furthermore, and supporting previous studies related to outsourcing (e.g., Berchicci, 2013; Grimpe and Kaiser, 2010), firms with a strong knowledge stock are more likely to leverage the benefits generated abroad via contract offshoring and captive offshoring.

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