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International R&D teams: Performance effects and the moderating role of technological competences

Daniel Sommer
University of Hohenheim, Germany

Bernd Ebersberger
University of Hohenheim, Germany

Abstract

Firms increasingly internationalize their R&D teams in order to exploit a broader range of inventor backgrounds and to benefit from local competencies. We analyze the effects of internationality in R&D teams, measured on a complete patent data sample by European firms. We measure team member internationality and include the level of technological competency at the inventors' locations in the relevant fields, through the Revealed Technological Advantage (RTA). With a quantile regression we break down our results for different levels of patent quality, compared to a baseline OLS. Our results indicate that while the effect of team internationality on patent quality changes from negative to positive over the patent quality distribution, the technological competence at the international inventor locations has a positive effect on patent quality at all levels of patent quality. For better performing patents, a high technological competence even strengthens the positive effects of internationalization, whereas in very low performing patents we observe a negative amplification. Therefore, internationalizing a research team does only pay off for medium or high-quality patents, whereas a high technological competence in the countries of inventors is always beneficial.

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Contact: Daniel Sommer - daniel.sommer@uni-hohenheim.de, Bernd Ebersberger - bernd.ebersberger@uni-hohenheim.de.
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1. Introduction

In an increasingly global world, businesses not only produce and sell internationally, but also conduct R&D with inventors located in several countries (Guellec and van Pottelsberghe de la Potterie, 2001).

The internationalization of R&D plays an increasing role in companies' ambitions to gain and maintain competitiveness, in which internationality of innovation teams is a key driver (Athukorala and Kohpaiboon, 2010; Belderbos, Lokshin and Sadowski, 2015; von Zedtwitz and Gassmann, 2002).

A significant portion of research has focused on internationality on a firm level and found ambivalent effects: on the one hand internationalization can pay off through the access to local talents, markets and the exploitation of market imperfections (Bagheri *et al.*, 2019; Criscuolo, Haskel and Slaughter, 2010; de Andrade, Galina and Ribeiro, 2015; Dunning, 1973, 1988; Hsu, Lien and Chen, 2015; Thursby and Thursby, 2006). On the other hand, higher coordination costs, higher fixed costs, higher transaction costs through the lack of networks are factors which can benefit a rather home-base centralized R&D over an internationalized one (Bausch and Krist, 2007; Blanc and Sierra, 1999; Erdener and Shapiro, 2005; Hurtado-Torres, Aragón-Correa and Ortiz-de-Mandojana, 2017; Kafouros *et al.*, 2018; Kafouros *et al.*, 2008).

These studies have usually focused on firms from a certain country (Añón Higón, Manjón Antolín and Mañez, 2011) or region (Sachwald, 2008), a certain industry (Grimes and Miozzo, 2015) or investigated general patterns of R&D internationalization and the global sourcing of knowledge (Le Bas and Sierra, 2002; Moncada-Paternò-Castello, Vivarelli and Voigt, 2011; Narula and Zanfei, 2005; Patel and Vega, 1999; Zanfei, 2000).

Complementing the aforementioned widely used analyses on the firm level, which implicitly assumes a homogeneous internationalization within the firm, in this paper we focus on the R&D teams (von Zedtwitz and Gassmann, 2002). We thereby allow for differences in R&D internationalization across the companies' numerous teams and R&D projects.

In this paper we investigate the role of internationalization of research teams on team performance and how this is affected by the competence at the team members' or inventors' international locations.

Prior research has outlined the positive effects of team internationalization through the variety in national or ethnic backgrounds (Banks and Banks, 2016; Boone *et al.*, 2019; Bouncken, Brem and Kraus, 2015; Earley and Mosakowski, 2000; Elron, 1997; Harrison and Klein, 2007): With a diversity in backgrounds, the range of knowledge is broader and the teams have more experience with different environments (Gassmann and von Zedtwitz, 2003; Nielsen and Nielsen, 2013). The internationality strengthens knowledge spillovers (Giuliani, Martinelli and Rabellotti, 2016; Xiang *et al.*, 2013). However, having international teams is not automatically beneficial due to higher transaction and coordination costs as well as cultural and geographic distances (von Zedtwitz *et al.*, 2018). With an overall increased complexity R&D internationalization requires additional planning and management (Chen, Huang and Lin, 2012).

Hypothesis 1: R&D team internationality correlates with R&D team performance.

A main argument of internationalizing R&D is the access to local knowledge and talents (von Zedtwitz and Gassmann, 2002). A company strives to increase its available knowledge pool by expanding into countries where competencies in relevant fields can be captured and learning effects can be induced (Fu, Pietrobelli and Soete, 2011; Giuliani, Martinelli and Rabellotti, 2016; Laurens *et al.*, 2015; Le Bas and Sierra, 2002).

Hypothesis 2: The level of technological competency at the inventors' locations in the relevant fields correlates with R&D team performance.

Technological competencies vary across the world, so the decision to internationalize R&D can be connected to a respective local level of technological competency (Awate, Larsen and Mudambi, 2015; Fletcher and Harris, 2012; Poon and MacPherson, 2005).

Hypothesis 3: The level of technological competency at the inventors' international locations moderates the correlation of the team's internationality and team performance.

Most studies have focused on the mean when analyzing these hypotheses. Additionally, we investigate how the effects change along the distribution of the team performance.

2. Methodology and Data

Patents provide a good data source to capture the scope of R&D internationalization (Hall, 2011). Hence, we base our analysis on patent applications to the European Patent Office (EPO), as provided by the OECD (OECD, 2020c) complemented with patent citations and quality indices (OECD, 2020a, b). Our analysis includes all patents by applicants located in the European Union (EU-28) over the available time-frame since 1977. Eliminating observations with missing information leads to a sample of 923,931 patents. In our case patents are a good data source as a patent identifies the team members who have invented the technology captured in the patent. Patents also provide information on the geographical location of each of the team members.

Variables

We measure R&D team performance through the composite Patent Quality Index 6 (PQI6), which combines six individual measures of patent quality: number of forward citations (up to five years after publication), number of backward citations, number of claims, patent family size, patent generality index and grant lag index (Squicciarini, Dernis and Criscuolo, 2013). A composite index can be more robust and reliable compared to a single indicator (Lanjouw and Schankerman, 2004).

To capture R&D team internationality, we use a dummy taking the value of 1 for a patent with at least one international inventor, i.e. an inventor not located in the country of applicant(s) and 0 otherwise. A robustness check with the variable capturing internationality being continuous, i.e. indicating the share of foreign to total inventors, delivered structurally similar results.

Technological competence of the team member's location is measured through a patent's Normalized Revealed Technological Advantage (NRTA) (Le Bas and Sierra, 2002). We calculate $RTA_{ijt} = \frac{P_{ijt}/\sum_j P_{ijt}}{\sum_i P_{ijt}/\sum_{ij} P_{ijt}}$ where P: number of patents, i: three-digit IPC class (International Patent Classification) (WIPO, 2020), j: Country, t: Year.

We normalize the RTA: $NRTA = (RTA - 1)/(RTA + 1)$, so that $NRTA \in [-1,1]$ (Nesta and Patel, 2004, 537).

In addition, we control for the average quality index with respect to the priority year of the patent application, the IPC class, and the patent applicant country / countries. We furthermore control for the number of inventors and the number of applicants for each patent. Table I presents the descriptive statistics.

Table I: Descriptive Statistics

Variable	Mean	SD	Min	Max
Dependent Variable				
Patent Quality Index 6 (PQI6)	0.311	0.085	0.036	0.86
Independent Variables				
International Patent (Dummy)	0.196	0.397	0	1
Normalized RTA	0.057	0.206	-0.946	0.996
Controls				
No. of Inventors on Patent	2.335	1.634	1	31
No. of Applicants on Patent	1.085	0.358	1	22
Average PQI6 Priority Year	0.309	0.014	0.255	0.375
Average PQI6 IPC	0.317	0.012	0.243	0.354
Average PQI6 Applicant Countries	0.311	0.008	0.251	0.363

Note: Descriptive Statistics for all analyzed patent data (N = 923,931)

Methods

We suspect that the effects of our independent variables vary depending on the respective level of the dependent team performance variable. Analogous to research conducted e.g. by Ebersberger and Herstad (2013), we use a linear quantile regression model as introduced by Koenker and Bassett (1978). The OLS regression serves as a benchmark.

We write a linear regression model as $y_i = x_i\beta + u_i$, where y_i is the dependent variable, x_i a vector of regressors, β a vector of parameters to be estimated and u_i a vector of residuals. The OLS estimator is obtained by minimizing $\sum(y_i - x_i\beta)^2$.

In a quantile regression we trace the complete conditional distribution of y conditional on x (Buchinsky, 1998), where τ represents the different quantile levels with $\tau \in (0,1)$ and $Q(\tau) = \inf\{y\colon F(y) \geq \tau\}$ and where $F(y) = P(Y \leq y)$ is the distribution of the random variable Y. We obtain the quantile regression estimator by minimizing (1):

$$\sum_{i \in \{i:y_i \geq x_{i\beta}\}} \tau|y_i - x_i\beta| + \sum_{i \in \{i:y_i < x_{i\beta}\}} (1-\tau)|y_i - x_i\beta| \tag{1}$$

3. Results

The OLS regression shown in Table II indicates that both internationality in the inventor team and a higher level of RTA in the involved countries have a significant positive effect, both individually, as well as in interaction on patent quality. A higher RTA therefore even strengthens the positive effects of internationalization.

The quantile regression, as illustrated in Figure 1 and detailed in Table II, shows a more nuanced picture. For the 60% quantile and above, the findings are similar to the findings from the OLS regression. For lower quantiles the results differ markedly: for low performing patents up to the 20% quantile, internationality has a significant negative effect. At the 30% quantile there is no significant effect and only from the 40% quantile upwards, internationality has a significant positive effect on patent quality. The effect of the RTA is always significantly positive.

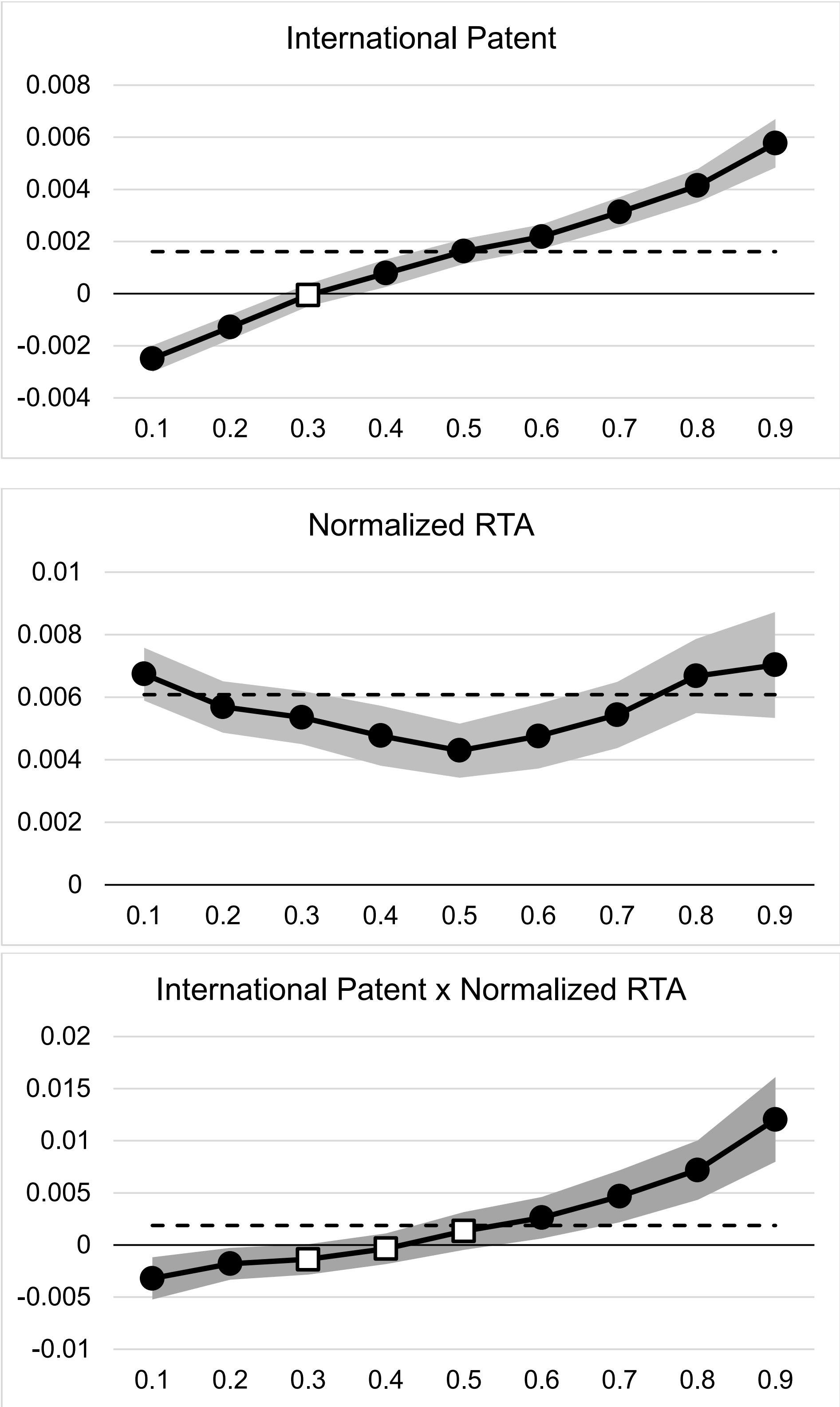
The interaction effect is only significantly positive for the 60% quantile and above. This means that only for the top quantiles a higher RTA increases the positive effects of internationality. For the 10% and 20% quantile the interaction effect is even significantly negative. Here the negative effects are amplified by higher competencies at the international inventor location. The interaction is only positive for the better performing patents, where the direct effect of internationalization is positive as well. Here, higher competencies amplify the positive effects of international team composition on team performance.

Table II: Results of OLS and selected quantiles of quantile regression for PQI6

		Quantile Regression		
Variable	**OLS**	$\tau = 0.1$	$\tau = 0.5$	$\tau = 0.9$
International Patent	0.0016***	-0.0025***	0.0016***	0.0058***
	(0.0002)	(0.0003)	(0.0003)	(0.0006)
Normalized RTA	0.0061***	0.0067***	0.0043***	0.0070***
	(0.0005)	(0.0005)	(0.0005)	(0.0010)
International Patent x Normalized RTA	0.0019*	-0.0032***	0.0013	0.0121***
	(0.0010)	(0.0012)	(0.0011)	(0.0025)
No. of Inventors on Patent	0.0047***	0.0013***	0.0042***	0.0088***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
No. of Applicants on Patent	-0.0031***	-0.0027***	-0.0026***	-0.0033***
	(0.0002)	(0.0003)	(0.0003)	(0.0004)
Average PQI6 Priority Year	0.8411***	1.0265***	0.7483***	0.7982***
	(0.0062)	(0.0085)	(0.0055)	(0.0160)
Average PQI6 IPC	1.3980***	1.2315***	1.3442***	1.6245***
	(0.0075)	(0.0109)	(0.0103)	(0.0161)
Average PQI6 Applicant Countries	1.1424***	0.7106***	1.0923***	1.6093***
	(0.0116)	(0.0130)	(0.0138)	(0.0322)
_cons	-0.7559***	-0.7134***	-0.7033***	-0.8616***
	(0.0048)	(0.0063)	(0.0053)	(0.0121)
(pseudo)R2	0.0669	0.0549	0.0321	0.0337
Observations	923,931	923,931	923,931	923,931

*Note: Dependent Variable: Patent Quality Index 6 (PQI6), *** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses, Values rounded to four digits.*

Figure 1: Graphical illustration of OLS and quantile regression estimates



Notes:

Horizontal axis: respective quantile

Vertical axis: estimated parameter

Black line: estimated parameters of quantile regression

Round filled marker: significant estimate ($p<0.1$)

Square unfilled marker: not significant estimate ($p\geq0.1$)

Black dashed line: OLS estimate

Grey shadowed area: 90% confidence interval

Thin black line: zero line for reference

4. Conclusion

Our findings provide novel insights for the discussion about R&D team internationalization. We contribute and expand on previous research in four ways: First, we focus on the team level on a large scale, instead of the largely regarded firm level and thereby give insights into an additional level of R&D. Second, we expand on previous research (e.g. Giuliani, Martinelli and Rabellotti, 2016) methodologically, by analyzing the performance implications of R&D teams through a composite index, including i.a. patent citations. Third, we include the level of technological competency at the inventors' locations with the established measurement of Revealed Technological Advantage (RTA). Fourth, we analyzed not only the means, but also the change of effects along the distribution of the outcome.

On the micro level our findings mean that internationalization contributes to the team performance of medium to good performing teams. It seems to hamper team performance in low performing teams. High level of competence level at the team members' international locations will amplify the effects. International team composition matters for team performance.

This finding is consistent with prior research, which shows that R&D internationalization does not increase performance under every circumstance (Gassmann and von Zedtwitz, 1998).

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