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**LINKING R&D INVENTORS' SOCIAL SKILLS AND BRICOLAGE TO R&D
PERFORMANCE IN RESOURCE CONSTRAINED ENVIRONMENTS IN
EMERGING MARKETS**

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Abstract

High-tech organizations increasingly rely on innovative contributions of their R&D employees, or the *inventors*, who often work within resource-constrained environments of emerging markets to deliver innovative outcomes. Integrating social exchange theory and bricolage theory, we conceptualize R&D activity as a process that involves salient tensions as inventors work effectively with others using their social skills while pursuing competing goals, with limited capital, and resource constraints. This study extends prior research on the relationship between R&D inventors' bricolage activities, their social skills and R&D performance. Survey data was collected from 211 R&D inventors working in R&D divisions at six multinational high technology organizations in India. Results indicate that R&D inventor bricolage activities enhanced R&D performance (outcomes and efficiency). We also find inventors' social skills (social astuteness, networking ability, interpersonal influence and apparent sincerity) significantly relate to R&D inventor bricolage and positively relate to R&D project outcomes. This study provides empirical evidence towards uncovering the behavioral foundations of R&D inventor activities in resource-constrained R&D settings. We identify social skills and bricolage activities of R&D employees as being important for shaping positive R&D outcomes in organizations. Overall, we contribute to R&D management in better understanding how micro-level variables influence macro-level R&D outcomes in firms.

Index Terms

R&D management, innovation, bricolage, social skills, performance, resource constraints, emerging markets, R&D inventors

Managerial Relevance Statement

Our research has primary relevance on managing R&D performance (outcomes and efficiency) in high technology domains in the contexts of emerging economies that impose resource constraints. Our empirical results support past research on the importance of bricolage (making do with what is available at hand) in enabling R&D performance under resource constraints. We also find that R&D inventors' social skills (social astuteness, networking ability, interpersonal influence and apparent sincerity) are salient in enabling bricolage by inventors towards enhancing R&D performance. Social skills leverage inventors' ability to reconstruct and recombine limited resources towards innovative outcomes. Therefore, high technology firms operating in resource constrained contexts should offer R&D inventors an enabling and open innovation environment to learn through collaboration and experimentation with active reuse, recombination and reconstruction of existing resources. Managers in such firms may benefit by recruiting R&D inventors who are naturally high on both social skills and bricolage ability (assuming they meet the bar on specialized technical skills) who will thrive in an open innovation environment. Managers could also enable R&D inventors to improve their social skills and bricolage ability possibly through structured training and develop both collaborative and frugal mindsets over time.

Introduction

R&D activities produce scientific and technological advancements that allow organizations to develop innovations in products or processes [1, 2]. The R&D units in emerging economies often work with higher risks of failures, highly uncertain goals and higher resource constraints when compared to their counterparts in developed economies [3, 4]. In emerging economies, organizations regularly deal with turbulent technological and market environments that limit access to resources to produce innovative products to stay competitive in their markets [5, 6].

One aspect of literature in the field suggests that organizations can indeed produce more innovations and more viable offerings while operating under resource constraints [7-11]. The perspectives of *bricolage*, *frugal innovation*, and *resource constrained product development* offer workable approaches to understand how organizations under resource constrained environments are developing innovations, new products and processes [11-16]. For instance, Agarwal, et al. [11] mapped different concepts related to constraint-based innovations, such as *jugaad*, *bricolage*, and *disruptive*, *frugal*, *catalytical* innovations, among others. However, the exact relationships between inventors involved in *bricolage* and *frugal innovation* activities and their R&D and innovation outcomes remains a topic of ongoing debate [17]. On one hand, some studies show entrepreneurs, individuals operating in entrepreneurial ventures, small and medium sized enterprises (SMEs) and large organizations combating high resource constraints successfully by deploying reuse, recombination and improvisation techniques to produce innovative outcomes [16, 18-20]. On the other hand, a few studies also show how entrepreneurs and firms in emerging economies dealing with serious contextual limitations of minimum capital investments and limited resources, may witness some negative effects of applying approaches of “make-do” with the resources at hand under certain conditions [13, 19, 21, 22].

We argue that one notable reason for these mixed results is that existing studies often overlook or ignore to explicitly account for the crucial role of *bricoleurs* (inventors deploying

bricolage). Specifically, when and how *bricoleurs* deal with resource-constraints to successfully produce and efficiently deliver innovative performance, *outcomes* and *efficiency* respectively – two crucial determinants of innovation success in organizations [23]. In fact, different social and interpersonal abilities of inventors in organizations will reward them with different types of returns for their bricolage activities, such as gathering of different sets of technological, product and process knowledge, variations in acquiring, reusing and recombining of resources, and variations in ability to convince others in the organizations to support their activities, thus influencing the two overall innovation performance measures. We find that previous research studies have not addressed or explicitly considered this issue.

In this paper, we contribute to the existing research by focusing on two research gaps. First, this study hypothesizes and empirically validates how social skills of inventors in R&D settings influence the two dimensions of R&D performance differently: R&D outcomes (RDO) and R&D efficiency (RDE). Specifically, this study integrates the theoretical arguments of social exchange theory [24-26] that superior social skills – skills useful to individuals in interacting with others – exert strong effects on inventors’ abilities to undertake challenging work tasks, such as “make do with resources at hand”, leading to important performance and work outcomes in many situations [27-30] and bricolage theory [13, 18, 31, 32] to argue that bricolage activities positively influence R&D outcomes and efficiency. Second, this research provides direct linkages by which bricolage activities and the bricoleurs’ social skills interact and impact R&D performance. Specifically, drawing on social exchange theory, this study explores how ability to conduct bricolage activities are contingent on the levels of social skills, which influences resource gathering, reuse, recombination decisions and behaviors in organizational groups [29, 30, 33], while creating unique opportunities and challenges in R&D settings.

The contributions of this study are threefold. First, we add to existing research on the micro-foundations of bricolage by exploring individual level mechanisms of how social skills and bricolage activities of inventors in R&D settings influence success of their R&D pursuits. We show that by looking closely at the individual inventors, we can investigate how inventor's social skills, bricolage and performance are related. Specifically, by integrating social exchange theory, we show that bricolage activities are influenced by social interactions, as bricolage requires gathering useful information and in obtaining resource sets through the help of others in the organizations. Hence, we argue that social skills of inventors can shape and influence their bricolage activities while shaping the overall R&D outcomes and we provide empirical evidence to support the hypothesized relationships. Second, the study adds to the sparse literature on underlying mechanisms of how knowledge workers, such as the R&D inventors and employees, enhance and shape bricolage activities. We believe that this is an important instrument for emerging markets firms, where enhancing the capabilities of their R&D inventors to reuse, reconstruct and recombine resources can generate innovative outcomes under uncertain and resource constrained conditions. Third, we extend the literature on corporate entrepreneurship by exploring the innovative outcomes at the individual levels in dynamic R&D environments. The behaviors of individuals in R&D settings is important to understanding innovation efforts and outcomes in emerging economies.

The paper is organized as follows. First, we review and present the extant literature on bricolage and social skills as it is related to our broader research problem and setting. We then develop hypotheses relating inventor bricolage, inventor's social skills and their performance outcomes in R&D settings. Empirically, we then examine and test these hypotheses using primary data collected from R&D inventors operating in six high technology firms in India and present our results. We then discuss our findings and discuss the role of inventor social skills

and bricolage in shaping innovative outcomes in resource constrained environments, before discussing the limitations of our study, future research directions and conclusions.

Theory Development

Resources are defined as the tangible and intangible assets used to develop market offerings that have value for some market segments [34-36].¹ While, resources are essential to conduct experiments, test ideas and transform carefully chosen raw materials with specific technical expertise to generate new knowledge, products and services, inventors often deal with resource scarcity in R&D settings [37-39]. Operating under resource constraints, specifically in emerging economies, requires the ability to work with others to create new knowledge to develop innovations within the limitations.

Resource scarcity can have complex effects and often manifests in different ways [40]. An increasingly common issue, especially in emerging economies, is the need to innovate and successfully operate R&D work within the context of high resource constraints [11, 41]. Approaches of “making do” or bricolage have been found to be effective while dealing with high resource constraints and to manage organizational pressures to innovate effectively [7, 10, 18, 31, 42]. These heavily resource constrained settings require inventors to practice new approaches that allow applying limited human resources, technical expertise and constrained work hours to be able to generate innovative outcomes [18, 19, 31, 43]. Such high resource constraints also require inventors to be able to collaborate with others effectively, not only to combine relevant technical know-how and existing knowledge, but to also be able to access

¹ We use Hunt (1999) to define resources in this paper. These resources can be financial (cash reserves and access to financial markets), physical (tools, raw materials, equipment), human (skills, knowledge and expertise of individual employees and teams, including their innovative and entrepreneurial skills), informational (such as knowledge about technology, consumer needs, market segments, and competitors), relational (such as relationships between individuals, teams, competitors, suppliers, and consumers), legal (patents, trademarks and licensees), organizational (such as controls, routines, cultures), along with any other resources the firm or the individual has access to.

more resources through other inventors and scientists in the organization [7, 10, 18, 31, 40]. We view bricolage activities within resource constrained settings through a social exchange lens, where effective social exchange between inventors and their peers can result in maximizing resource gains and benefits for inventors and hence, enhance inventors' and organization's R&D outputs.

Possessing higher levels of social skills leads to higher performance and effectiveness in a variety of work settings and crucial organizational processes [27, 44, 45]. Those with higher social skills are often able to achieve higher work task levels or higher job performance [27, 46-50], including in the contexts of higher uncertainty, such as entrepreneurship and venture performance [29, 48, 51] and R&D [50]. Inventors using bricolage approaches may be able to handle collaborations and resistance from others more effectively when they possess superior social skills. Through enhanced social interactions and exchanges, inventors will approach resource scarcity and R&D activities within those scarce settings more effectively by utilizing effective social exchange within and even across organizations.

Characterizing R&D inventors and their bricolage activities in emerging markets

Bricolage

The approach of making do with whatever is available at hand has been termed as *bricolage* [52], where resource reconstruction through reusing and recombining allows individuals to create novel solutions while operating within resource and/or time constraints. The literature on entrepreneurship has incorporated and studied this concept to understand how such resource reconstruction processes can allow entrepreneurs and ventures to develop knowledge and innovative products [13, 18, 32, 53]. Furthermore, Kogut and Zander [54] have argued that the ability to generate new applications from existing sets of knowledge, also known as combinative capabilities, enhances learning and innovations at the firm level.

The literature on bricolage in emerging economies has developed further to understand how bricolage approaches help organizations to create frugal solutions and develop new knowledge, such as the case of Tata Ace (a low cost mini-truck from India) and the Indian Mars Mission, among others [55-60]. As individuals and inventors working in emerging economy firms often face contextual and organizational pressures to address problems and develop new solutions under extremely resource constrained environments [15, 61, 62], it becomes crucial to investigate how inventor bricolage gets shaped and shapes the overall R&D outcomes. Reflecting on this idea, we first develop hypotheses concerning the effects of bricolage and effects of social skills on R&D performance.

Effects of Bricolage on R&D Performance

Emerging literature on bricolage suggests that inventors, ventures and organizations operating under resource constrained conditions benefit from bricolage [7, 9, 63, 64]. Through effective reuse and novel combinations of existing resources at hand, bricolage can enhance development of innovative solutions and products [18, 65-67], service innovations [8, 40], and knowledge [54]. Extending this logic, bricolage could enhance R&D performance in two ways. First, inventors operating within high resource constraints can thrive by deploying bricolage to effectively generate new solutions by effectively *reusing* their existing knowledge. Corporate R&D settings encourage inventors to be able to generate multiple product ideas and solutions using the available sets of knowledge as developing new knowledge often requires intensive investments of capital, resources and time [21, 68]. For instance, development of products like Mahindra Reva (first efficient electric car from India) in emerging economies demonstrates how inventors often use existing knowledge and technology within resource constraints to create affordable and new products [58, 69]. Second, high levels of resource constraints force inventors to work with limited resources, capital, time and labor, under significant

organizational pressures to produce R&D results, forcing them to deploy *reconstruction* of resources to generate novel R&D outcomes. This resource reconstruction can involve utilizing the existing technologies to address newer problems in the market. For example, inventors used the existing technology of touch screens on phones to develop products for other markets and sectors, such as education, wearable devices and security systems. Hence, we hypothesize that R&D inventor's bricolage activities will have a positive impact on R&D performance.

Hypothesis 1: R&D inventor bricolage is positively related to R&D performance.

When inventors deal with limited and existing sets of tools, resources, knowledge and technologies to create new outcomes during their R&D projects, inventors often engage in reuse, recombination and reconstruction of what is available at hand [18, 59]. This process not only results in new applications for reconstruction of existing knowledge and technology, but also results in enhanced understanding and learnings about resources at hand. Thus, we hypothesize that R&D inventors' bricolage will positively impact R&D outcomes.

Hypothesis 1a: R&D inventor bricolage is positively related to R&D outcomes.

When inventors focus more on resource recombination, reuse and reconstruction, they are likely to save limited resources, energy and time in pursuing or requesting new resources via traditional approaches of gathering resources required for an R&D project [7, 13, 42]. Hence, inventors engaging in resource reconstruction could direct free-up resources such as time [22], energy and labor towards making progress in their R&D activities, allowing inventors to complete projects with shorter timelines and budgets. Hence, we hypothesize that R&D inventor bricolage will positively influence R&D efficiency.

Hypothesis 1b: R&D inventor bricolage is positively related to R&D efficiency.

Effects of R&D Inventor's Social Skills on R&D Performance

Mintzberg [70] argued that individuals must develop the abilities to persuade, influence, and control others in order to be effective and to achieve desired goals. Social skills are defined as the ability to understand others in social interactions and effectively use this knowledge to influence others at work in ways that enhances one's personal and/or organizational goals [27, 51, 71].

Researchers have identified different types of social skills that play a crucial role in shaping behaviors and performance in a variety of work settings. These include political skills that are complementary and overlap significantly with social skills [47, 72-75], networking skills, or *guanxi*, that overlaps with networking ability skills which have been found to be crucial for success and survival in environments like China [60, 76], and finally, interpersonal and emotional skills that allow individuals to effectively control and understand others' emotions to facilitate thinking and guide decision-making [49, 77-80]. Our arguments regarding the impact of specific social skills are based on the earlier research findings in the field of management [29, 30, 51, 81, 82].

In this study, we examine four specific skills – social astuteness, networking ability, interpersonal influence and apparent sincerity – drawn from the literature on social and political skills in the context of management, entrepreneurship and organizations [29, 30, 74]. We argue that skills related to ability to effectively and accurately understand interactions in social settings (social astuteness) play a crucial role when inventors are involved in bricolage activities in R&D environments. Inventors often search for suitable partners (networking ability) to work with, such as other inventors and their colleagues, to gather existing knowledge and information to enhance their own bricolage activities by attempting to access diverse resource sets available to them in their organizations. It is also essential for inventors to effectively understand and influence others (interpersonal influence), all the while appearing

to be genuinely working towards enhancing their R&D goals (apparent sincerity). These four skills should lead to overall positive organizational outcomes through R&D achievements. Hence, we argue that the social skills of R&D inventors will have a positive impact on R&D performance.

Hypothesis 2: R&D inventor's social skills are positively related to R&D performance.

In the context of high uncertainty, especially in R&D settings, inventors with high levels of social skills will benefit greatly from an enhanced understanding of social interactions [29] about expected goals and results from their R&D projects. These inventors will be able to understand and, if needed, influence others effectively to cooperate [50] for developing and reshaping the expected goals for the R&D project. With enhanced social skills, inventors can locate as well as make new connections that are best fitted for their R&D project [51]. Higher social skills will also enable inventors to convince their lead collaborators and key players in their organization about their specific plans and activities in the R&D project. Thus, we hypothesize that R&D inventors' social skills will positively impact R&D outcomes.

Hypothesis 2a: R&D inventor's social skills are positively related to R&D outcomes.

Higher social skills allow the inventors to have an enhanced understanding of expected R&D goals as well as the permissible boundaries for the R&D project, including the timelines and budgets. Inventors equipped with high social skills will also have effective networking skills [48, 50] to identify the right people and champions required at various stages of R&D project, resulting in savings of time, efforts and human labor. High social skills will also allow inventors to appear sincere in their R&D pursuits and to be able to convince others when the ongoing R&D project creates situations that require additional considerations, such as

extension of deadlines, requesting previously unlisted resources, among others. Hence, we hypothesize that R&D inventors' social skills will positively impact R&D efficiency.

Hypothesis 2b: R&D inventor's social skills are positively related to R&D efficiency.

Effects of R&D Inventor's Social Skills on Inventor Bricolage

In uncertain environments, it is essential to effectively understand and interpret social cues and interactions to understand others at workplaces [83-85]. Specifically, when goals are uncertain and unclear, individuals need to carefully and successfully assess who to work and collaborate with. Additionally, inventors need to be able to effectively understand the social exchanges between various work groups among other key players. These players could be other inventors with expertise in complementary fields, technical staff and managers. Inventors must carefully analyze others for potential collaborations in R&D work to be able to understand what patterns of resource reuse, reconstruction, and recombination are possible and will most likely produce fruitful results in conditions of uncertainty and resource constraints [10, 31, 53, 86]. During these processes of collaborating with other inventors and colleagues, it is essential for inventors to access information, skillsets, time, and resources possessed by others. The ability to influence others to gain access to their resources becomes important for inventors to acquire more resources, resulting in further expansion of their base set of resources at hand. By appearing sincere and genuine in their R&D pursuits and in their efforts, inventors are able to effectively influence their colleagues to provide them required access to their own critical resources for inventors' R&D work. Hence, we argue that R&D inventor's social skills play a positive role in enhancing R&D inventor's bricolage activities.

Hypothesis 3: R&D inventor's social skills are positively related to R&D inventor's bricolage.

Hypotheses are presented in the conceptual framework in Figure 1.

Insert Figure 1 here

Methodology

Data collection procedures and sample description

A survey was conducted using a list of high technology firms with significant R&D operations in India provided by the Ministry of Science & Technology, Department of Scientific & Industrial Research, Government of India. This list of high technology firms in India included sectors such as manufacturing, semiconductors, telecommunications and gaming devices. India presents a suitable context for conducting this research as it is an emerging economy with significant resource constraints for high technology firms involved in R&D. India is also a suitable setting for exploring bricolage in practice, as the term *jugaad* is widely used in India to describe improvised, innovative or out-of-the-box ways of solving a problem due to lack of resources.

The questionnaire was designed following the recommendations of Dillman [87], De Leeuw, et al. [88], and Dillman [89]. We carefully ordered the survey questions to disrupt potential inference between questions wherever possible [90, 91]. We also included additional (filler) unrelated questions and tasks in the survey for creating psychological separation between measurements of dependent and independent variables [90, 91]. As the survey was to be conducted in English, R&D managers from a large telecommunication firm were initially interviewed to check the appropriateness and face validity of the survey questions in the Indian context. Subsequently, a pilot test was performed on survey responses from 15 R&D managers to verify and refine the questionnaire. This pilot testing data was excluded from the final study.

For the final data collection, 70 random firms from the list received emails containing a letter of introduction and request for participation in return for findings and feedback reports. Interests were confirmed with six organizations during meetings and questionnaires along with

self-addressed envelopes were distributed. We distributed 800 questionnaires to R&D employees (scientists, researchers, technical staff members) who were working full time and led R&D projects in R&D divisions of these six high technology organizations in India, thus ensuring they had sufficient knowledge about each measure with regards to those R&D projects. We received 308 responses back from the respondents. We found that 93 returned surveys provided incomplete responses, resulting in an overall final sample of 211 responses, resulting in the response rate of 26.3% for this study.

Among 211 R&D inventors in our final sample, the average age was 36.5 years and 87.2% were male. In terms of education and work experience, 23.3% R&D inventors in our final sample possessed PhD or Doctoral Degrees and 41.9% possessed Master's or other advanced research degrees in their respective fields of expertise, with average R&D work experience being 5.7 years, and overall average corporate work experience being 13.5 years.

Measures

Dependent variables

The dependent variables are R&D performance measured through R&D outcomes and R&D efficiency, with regards to the inventor's last completed R&D project. Building on the work of Brettel, et al. [21], six items are used to measure R&D outcomes and three items are used to measure R&D efficiency. This is drawn from earlier studies [92, 93] that measured R&D performance through outcomes and efficiency dimensions. This approach is the most common method to measure project performance as informants often lack reliable insights into project's objective financial performance data [38]. Responses were taken on a seven-point Likert scale. The items are provided in Table 1.

Independent variables

The independent variable of bricolage was measured using eight items from Senyard, et al. [13], and Wu, et al. [22] to capture the extent of inventor bricolage during their last completed R&D project, that is if they used existing resources available at hand to cope with new problems and opportunities. Responses were taken on a seven-point Likert scale. Sample items from this measure, include “I use any existing resource that seems useful to responding to a new problem or opportunity”, “When I face new challenges, I put together workable solutions from our existing resources”. It was assumed that resources were constrained.

Following the works of Ferris, et al. [72], and Liu, et al. [73], 18 items are used to measure specific social skills using the inventory developed by Ferris, et al. [72] and validated and tested in other studies in various cultural settings [94, 95]. Responses were taken on a seven-point Likert scale. The items are provided in Table 1.

Insert Table 1 here

Control variables

Control variables used were age, gender, level of education, years of R&D experience and years of overall work experience as these variables are likely to impact R&D outcomes and R&D efficiency.

Reliability and validity

Exploratory factor analyses using SPSS software were used to identify if there were any underlying relationships between items of the measured variables and results revealed no cross-loadings between the different factors [96]. To assess variable reliability, Cronbach’s alpha coefficient estimates were used and are given in Table 2. It shows that the alpha values are 0.81 – 0.90, far exceeding the recommended threshold value of 0.7 [97].

We then performed confirmatory factor analyses using SPSS AMOS software to test reliability further as well as to establish convergent and discriminant validity. We found our variables to be highly reliable with composite reliability (CR) values over 0.8, which are more than the acceptable levels of 0.7 [98]. The results also revealed all items loaded significantly on their respective predicted latent factors, with loading values exceeding the 0.7 criteria [97]. The average variance extracted (AVE) for all variables were found to be close to or more than the recommended value of 0.5 [98], thus, indicating no major issues with convergent validity. Furthermore, the maximum shared variance (MSV) value was less than the AVE value and the square root of the AVE was greater than inter-construct correlations for all constructs, thus, indicating good discriminant validity [96]. The results are provided in Table 2.

Insert Table 2 here

Common Method Bias and Multicollinearity

We conducted multiple tests to check for common method bias. Firstly, Harman's one-factor test recommended by Harman [99] was conducted. This test revealed that all four factors explained 63.90% of the total variance and the first (largest) factor explained 29.67% of the variance, indicating no single factor explaining most of the variance among the model variables, thus demonstrating no significant common method bias [91, 100]. Secondly, following the common latent factor approach recommended by Liang, et al. [101], we found that path coefficients of the core model including bricolage, social skills, RDOs and RDE remained essentially the same after integration of an idle latent factor (model without common latent factor: (CMIN/df = 1.348, CFI = 0.951, RMSEA = 0.040, TLI = 0.945, IFI = 0.952, SRMR = 0.055); model with common latent factor: (CMIN/df = 1.247, CFI = 0.968, RMSEA = 0.034, TLI = 0.961, IFI = 0.968, SRMR = 0.048)). Finally, we followed the marker variable approach recommended by Lindell and Whitney [102] and included 'acknowledging surprises'

as a marker variable in the questionnaire to test whether common method bias could impact the results. The chosen marker variable was found to be unrelated to the dependent variables – RDOs ($r = -0.13$, ns) and RDE ($r = 0.06$, ns). Partial correlations between all model variables continued to remain statistically significant while controlling for the marker variable [86, 103]. Overall, these test results suggest little threat from common method bias and offer support for the validity of our measures for further analyses.

All variables are averaged, and independent variables have been centralized to avoid multicollinearity [104]. None of the correlations between the key variables were more than 0.5, indicating multicollinearity issues may be unlikely [105]. We then tested multicollinearity using the recommended approach of variance inflation factor (VIF) [106]. The analysis revealed that all VIF values ranged between 1.03 and 2.80, which is much less than the recommended value of 5 [106, 107].

Results

We present the items for each factor, summaries of each variable and pair-wise correlations between variables in Table 1 and Table 2. We find that independent variable, inventor bricolage, is positively correlated to R&D outcomes and R&D efficiency. Inventor's social skills are also positively correlated to R&D performance – outcomes and efficiency. We also find that inventor bricolage and inventor's social skills were also positively correlated to one another. These significant correlation results provided initial support for further analyses of our hypothesized relationships.

Hierarchical linear modeling (ordinary least square (OLS) regression) was used to test the hypothesized relationships [108, 109] using SPSS software and the results are presented in Figure 2 and Table 3. The variable of R&D outcomes was entered into the regression model as the dependent variable in Model 1 to Model 3, while R&D efficiency was entered as the

dependent variable in Model 4 to Model 6. Inventor Bricolage was entered as the dependent variable in Model 7. We began our tests by entering control variables of age, gender, years of R&D experience, years of work experience, and education as independent variables in Model 1 and Model 4 to test their effects on the dependent variables of RDOs and RDE. We find these effects are non-significant. These control variables were included in all models among key independent variables, from Model 1 to Model 7.

Furthermore, in Model 2 and Model 5, we entered inventor bricolage as independent variable along with control variables for testing hypotheses 1 (1a and 1b) to test the effect of inventor bricolage on R&D outcomes and efficiency. We find that inventor bricolage positively affects R&D outcomes ($\beta = 0.400$; $p < 0.001$) and R&D efficiency ($\beta = 0.407$; $p < 0.001$), thus supporting hypotheses H1 (1a and 1b). We then entered inventor's social skills as an independent variable along with other independent variables, inventor bricolage and control variables, in Model 3 and Model 6 for testing hypotheses 2 (2a and 2b) to examine the effects of inventor's social skills on R&D outcomes and efficiency. We find that inventor's social skills positively affect R&D outcomes ($\beta = 0.326$; $p < 0.001$) and efficiency ($\beta = 0.163$; $p < 0.01$), supporting our hypotheses 2 (2a and 2b).

Finally, in Model 7, we enter inventor bricolage as the dependent variable and inventor's social skills along with control variables as independent variables to test the hypothesis 3 for testing the effect of inventor's social skills on inventor bricolage. We find support for hypothesis 3 in Model 7 as we find positive effect of inventor's social skills on inventor bricolage ($\beta = 0.426$; $p < 0.001$). Thus, these results from Model 1 to Model 7 fully support our three hypotheses. Figure 2 provides the visual representation of the results from Model 2, Model 5 (hypotheses 1a and 1b), Model 3, Model 6 (hypotheses 2a and 2b) and Model 7 (for hypothesis 3). We also tested our proposed model using structure equation modeling and found consistent results for these hypothesized relationships.

Insert Figure 2 and Table 3 here

Discussions

There have been several calls for scholarly research on understanding processes, practices and micro-foundations of how resource constraints and scarcities shape innovations and product development [12, 13, 57, 110, 111]. In this research, we found empirical support for the hypothesized effects of inventor bricolage and inventor's social skills on R&D outcomes and efficiency with survey data from 211 R&D inventors in hi-technology organizations in India. Specifically, we found support that inventor's social skills can influence bricolage and R&D performance.

First, the results showed that inventor bricolage correlates with R&D performance – outcomes and efficiency. Earlier research has shown that availability of resources is positively related to product development outcomes [112], but inventors cannot solely rely on ready availability of adequate resources for ensuring success of their R&D projects. Specifically, when resources are highly constrained, inventors can turn to bricolage for resource construction [10, 18, 43, 65] to achieve R&D outcomes efficiently. Although R&D inventors face resource constraints, their abilities to deal with resource constraints and their approaches of reuse and recombination of limited resources can have a positive impact on their R&D outcomes to efficiently produce innovations. This result aligns with the concept of the *frugal mindset* – an inventor's ability to make good use of available technical resources and R&D budgets rather than waiting for the most appropriate technical resources and an enhanced R&D budget. Moreover, in emerging markets, the frugal use of locally available technical resources may lead to the development of more contextually appropriate innovations at lower costs, that suit the local market needs better. This also implies that adequate bricolage skills and a frugal

mindset should be key additional areas to consider while recruiting inventors and while creating new R&D team structures within and across organizations.

Second, the results showed that inventor's social skills are critical and enhance inventor bricolage activities as well as R&D performance. Thus, social skills of inventors are essential to make inventors' social interactions more effective for increasing their success through bricolage. Similar to previous studies in other work settings, our study finds that R&D inventor's social skills indeed enhance their R&D work performance by enhancing their abilities to translate social exchange into meaningful resources and knowledge, which then contributed to their R&D outcomes. Socially skilled inventors can convert their social transactions into better progress with their R&D pursuits, such as gaining access to new information or knowledge, negotiating with peers for delivery of tasks in R&D projects, and producing novel knowledge through building effective collaborations. High social skills can also allow inventors to use their social transactions to source newer combination of resources to skillfully enhance and improve their R&D activities. In contrast, inventors that have lower social skills may struggle to effectively collaborate, convince, and negotiate with others, hence overall impeding their ability to work within high resource constraints to produce product innovations and improve their R&D performance. This aligns with the view that good inventions are more likely to be the outcome of a social process among a larger loose network of highly skilled specialists (also called *open innovation*), rather than the outcome of the solitary pursuit of genius inventors or a small team working in isolation. Social processes require adequate social skills and a more *collaborative mindset*. This implies that adequate social skills and a collaborative mindset should also be key areas to consider while recruiting inventors and while creating new R&D teams within and across organizations.

Managerial Implications

Our research indicates that R&D inventors and their managers are well advised to focus on appropriately recombining and reconstructing resources at hand in the context of resource constraints. They could consider resource constrained settings as an opportunity rather than a threat, to rethink their approaches to produce innovations. Instead of waiting for new resources, especially when technology evolves rapidly in high technology sectors, it is prudent to proceed with a resource construction approach. This also aligns with the idea of systematic inventive thinking using “inside the box” techniques popularized by Boyd and Goldenberg [113] that is followed by many corporations today.

Our research also indicates that the inventors’ ability to appropriately respond to high resource constraints is influenced by the inventors’ social skills. Therefore, it is crucial that managers focus on enhancing, developing and encouraging these social skillsets among inventors in their R&D divisions, along with encouraging the development of their technical skills and technical knowledge base. That is, when R&D managers and top management seek to enhance R&D performance within high resource constraints, they should encourage inventors and scientists to use their larger network, existing resources and social skills to effectively collaborate with others to build new knowledge through resource construction. This is preferable to waiting for the required resources to be acquired or to avoid some R&D pursuits in the absence of required resources. Recruiters of inventors (scientists, engineers and technicians) who are typically oriented towards examining parameters like research and technical skills should also train themselves to also identify social skills and bricolage skills among their candidates. While research and technical skills would naturally have primary importance, it may be prudent to provide specific training on bricolage skills and/or social skills to those inventors who lack them or wish to develop their further.

This research provides hope for organizations in emerging markets that operate under resource constraints, that outstanding and relevant innovations are possible even under severe resource constraints. It also provides potential pathway for organizations in emerging markets that operate under resource constraints to gear their R&D units better to overcome their constraints and look towards a positive future based on internally developed innovations.

Limitations & Future Research Directions

Future research should address some limitations of this research. First, although India is an appropriate research site for examining resource constrained R&D activities and bricolage effects on R&D performance as it is an emerging economy, it would be ideal to collect data from other emerging economies to reinforce these findings. Second, future research should examine other dimensions of inventor bricolage, such as frugal mindset, knowledge of customers/markets, their institutional and regulatory environments [18], nature of their R&D collaborations and networks [35, 43] as these factors may also influence R&D performance. Third, as cross-sectional data may make drawing causal relationships difficult [62, 114, 115], future studies should look into other approaches, such as experiments, longitudinal research studies and multi-wave survey studies, to examine relationships and causal effects between inventor's social skills, inventor bricolage and R&D performance. Future empirical studies can also focus on further minimizing common method bias by using multi-sourced datasets. Furthermore, future studies can also further reduce biases around retrospective reporting of successful R&D projects by using objective measurements of R&D performance, tracking live projects or using data points collected from R&D projects in real time. Finally, future research can also look into other environmental and contextual factors that can influence inventor bricolage and its relationships with performance, such as leadership support, environmental turbulence and regulatory volatility [116, 117].

Conclusion

This research makes three theoretical contributions. Firstly, it highlights the need to study inventors' behaviors for a more nuanced understanding of the inventor bricolage-performance relationship in highly resource constrained environments by proactively examining the effects of inventor's social skills on inventor bricolage and R&D performance. These findings extend the propositions that higher social skills can foster superior task performance [27, 48, 50, 51], particularly in the contexts of uncertain work settings of R&D in highly resource scarce surroundings. This study further refines our understanding on inventor level differences that influence inventor bricolage. Collectively, these findings add clarity on how the social skills of inventors can foster R&D success. We thus contribute to the growing literature on social exchange and research on social skills in R&D settings.

Second, despite the mixed evidence on positive effects of bricolage on innovative outcomes in resource constrained environments [19], few studies examine varying bricolage benefits in R&D settings through studying underlying individual processes and dynamic behavioral mechanisms for these effects [62]. This study provides evidence on positive effects of inventor bricolage on R&D performance and offers further empirical evidence supporting the positive relationships between bricolage and outcomes, along with bricolage and efficiency in R&D settings. As R&D environments in high technology industries witness rapid technological changes and evolution, timely resource reconstruction can influence efficient development of innovations. Therefore, the research presents the relationship between bricolage and R&D performance for a deeper understanding of the value of bricolage to conduct R&D activities in resource constrained environments. Overall, these findings contribute to the literature on effects of bricolage on R&D outcomes in highly resource constrained environments.

Finally, we contribute to the literature on understanding behavioral drivers and individual differences of bricoleurs (individuals engaging in bricolage) by a more nuanced understanding on factors that differentiate effective bricolage activities that consistently lead to innovations from simple occasional bricolage activities that do not result in innovations. By understanding the individual differences further, we gain more insights on successful bricoleurs and their skills. Therefore, the study contributes to the literature on bricoleurs – individuals who deploy bricolage approaches – to successfully produce innovations.

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Figure 1. Conceptual Framework

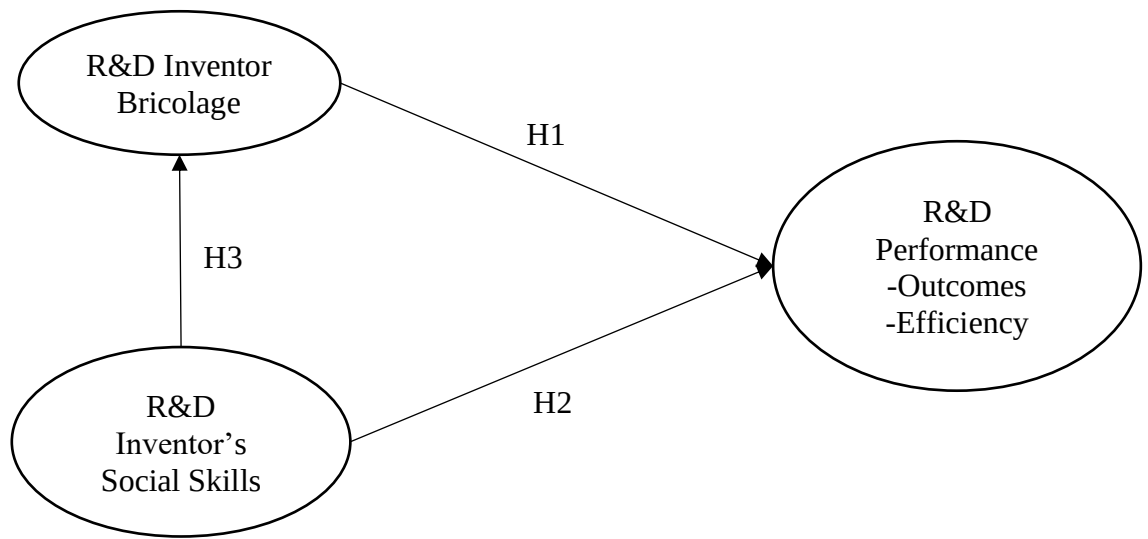


Figure 2. Results of Hierarchical Regression Analyses

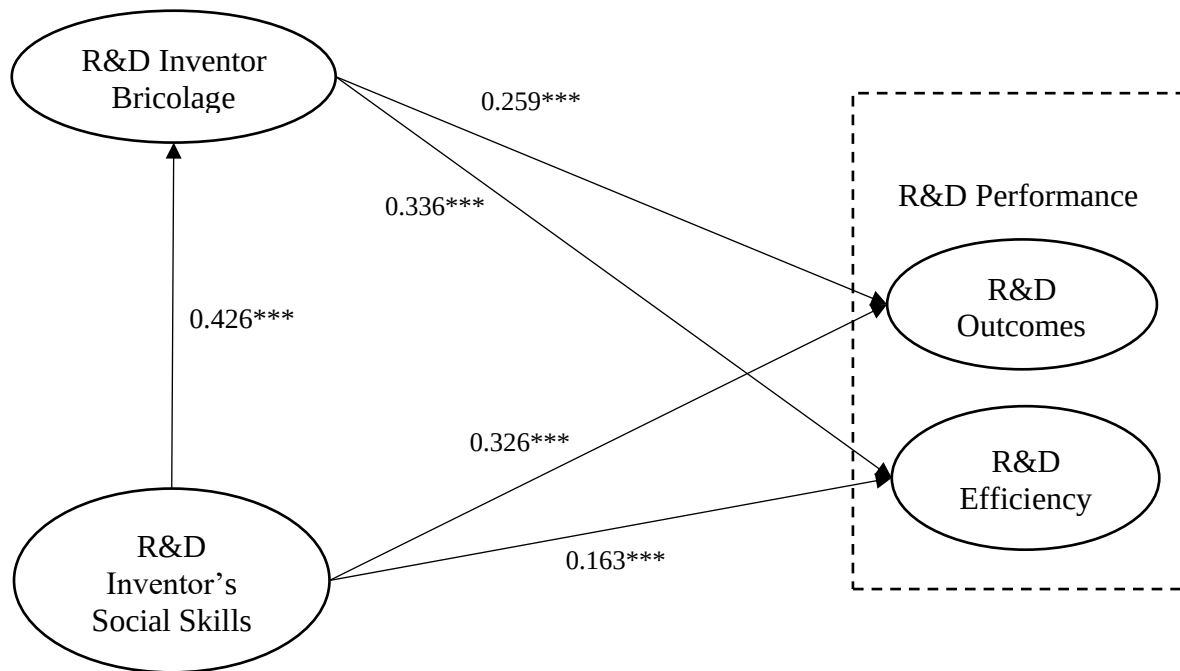


Table 1. Measures

Factors	Items
Inventor Bricolage	1) I was confident of our ability to find workable solutions to new challenges by using our existing resources. 2) I gladly took on a broader range of challenges than others with our resources would be able to. 3) I used any existing resource that seemed useful to responding to a new problem or opportunity. 4) I dealt with new challenges by applying a combination of our existing resources and other resources inexpensively available to me. 5) When dealing with new problems or opportunities, I took action by assuming that I will find a workable solution. 6) By combining our existing resources, I took on a surprising variety of new challenges 7) When I face new challenges, I put together workable solutions from our existing resources. 8) I combined resources to accomplish new challenges that the resources weren't originally intended to accomplish.
Inventor's Social Skills	1. I spend a lot of time and effort at work networking with others. 2. I am able to make most people feel comfortable and at ease around me. 3. I am able to communicate easily and effectively with others. 4. It is easy for me to develop good rapport with most people. 5. I understand people very well. 6. I have developed a large network of colleagues and associates at work who I can call on for support when I really need to get things done. 7. I am good at building relationships with influential people at work. 8. I am particularly good at sensing the motivations and hidden agendas of others. 9. When communicating with others, I try to be genuine in what I say and do. 10. At work, I know a lot of important people and am well connected. 11. I spend a lot of time at work developing connections with others. 12. I am good at getting people to like me. 13. It is important that people believe I am sincere in what I say and do. 14. I try to show a genuine interest in other people. 15. I am good at using my connections and network to make things happen at work. 16. I have good intuition or savvy about how to present myself to others. 17. I always seem to instinctively know the right things to say or do to influence others. 18. I pay close attention to people's facial expressions.
R&D Outcomes	Experiences and Competencies The R&D project met its expectations in terms of the ... 1) Learnings and expertise that can be leveraged in other projects 2) Generation of new ideas as starting point of potential future projects 3) Enhancement of competencies and capabilities Perceived Value and Future Potentials The R&D project met its expectations in terms of the ... 1) Perceived value of the R&D output 2) Opportunities to market R&D output 3) Quality and performance of the R&D output
R&D Efficiency	Overall Efficiency The R&D project met its objectives and expectations in terms of ... 1) meeting project schedule 2) staying on budget 3) meeting operational and technical performance of the R&D process

Table 2. Descriptive Statistics, Correlations, Estimates for Reliability and Validity.

	Mean	SD	α	CR	AVE	MSV	1	2	3	4	5	6	7	8
1. Inventor's Social Skills	5.18	0.64	0.90	0.84	0.57	0.34	0.76							
2. Inventor Bricolage	5.50	0.83	0.82	0.82	0.45	0.28	0.43**	0.65						
3. R&D Outcomes	5.40	0.95	0.81	0.87	0.54	0.34	0.45**	0.41**	0.73					
4. R&D Efficiency	5.49	0.82	0.88	0.81	0.59	0.33	0.32**	0.40**	0.46**	0.77				
5. Age	36.47	5.74					0.09	0.10	0.14*	0.05				
6. Gender	1.13	0.34					-0.04	-0.10	-0.05	-0.09	-0.13			
7. R&D Experience	67.91	44.53					0.09	0.00	0.16*	0.12	0.27**	-0.08		
8. Work Experience	161.46	58.68					0.07	0.06	0.07	0.01	0.80**	-0.14*	0.25**	
9. Education	2.12	0.77					0.01	-0.14	-0.08	0.08	-0.25**	0.07	0.15*	-0.18**

Note: N = 211.

SD = Standard Deviation; CR = Composite Reliability; AVE = Average Variance Extracted; MSV = Maximum Shared Variance

Cronbach alpha (α) is coefficient alpha reliability estimates for scale measures. Square root values of AVE are provided on the diagonal in bold.

* $p < 0.05$ (two-tailed).

** $p < 0.01$ (two-tailed).

Table 3. Results of Regression Analyses

Variables	R&D Outcomes			R&D Efficiency			Inventor Bricolage
	Model 1	Model 2 (H1a)	Model 3 (H2a)	Model 4	Model 5 (H1b)	Model 6 (H2b)	Model 7 (H3)
Inventor Bricolage		0.400***	0.259***		0.407***	0.336***	
Inventor's Social Skills			0.326***			0.163**	0.426***
Age	0.169	0.122	0.109	0.119	0.071	0.065	0.079
Gender	-0.027	0.008	0.007	-0.089	-0.053	-0.054	-0.074
R&D experience	0.148	0.150	0.129	0.094	0.097	0.086	-0.032
Work experience	-0.115	-0.089	-0.091	-0.105	-0.079	-0.080	-0.054
Education	-0.073	-0.029	-0.051	0.081	0.126	0.115	-0.119
F	1.928*	8.500***	11.578***	1.293	8.011***	7.803***	9.111***
R ²	0.045	0.200	0.285	0.031	0.191	0.212	0.211
Adj R ²	0.022	0.176	0.261	0.007	0.167	0.185	0.188
R ² change			0.085***			0.021*	

Note: N = 211. Significance levels are based on two-tailed tests for all models and coefficients.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.