



When does community participation enhance the performance of open source software companies?☆

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ABSTRACT

This study examined how participation in open innovation communities influences the innovative and financial performance of firms commercializing open source software. Using an original dataset of open source companies in the Netherlands, I found that the community participation–performance relationship is curvilinear. In addition, results indicate that extensive technical participation in open source projects is more strongly related to performance for firms that also engage in social (“offline”) community activities, for companies of larger size, and for firms with high R&D intensities. Overall, this research refines our understanding of the boundary conditions under which engagement in community-based innovation yields private returns to commercial actors.

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1. Introduction

Open source software (OSS) communities constitute collections of individuals and firms that contribute to the provision of a public good by freely sharing their innovations with other community members (Von Krogh, 2006). In so doing, contributors may capture important private benefits including enjoyment, elevated reputations, better career prospects, learning, and access to valuable resources (Hertel et al., 2003; Lakhani and Von Hippel, 2003). The “private-collective” innovation model (Von Hippel and Von Krogh, 2003) in particular postulates that the private rewards to active contributors are significantly greater than the benefits derived from free-riding behavior, an assumption that remains largely untested in the context of community participation by commercial firms (Lerner and Tirole, 2002).

Firms have indeed become increasingly involved in the OSS movement (Bonaccorsi et al., 2006), yet empirical evidence is lacking on how the nature of a firm’s community participation influences its performance (West and Lakhani, 2008). Recent research has noted both the potential benefits and downsides that accrue to firms making extensive contributions to OSS communities (e.g., Dahlander and Wallin, 2006; Grand et al., 2004; Miller et al., 2009), thus suggesting that firms must strategically participate in the

communities by appropriately balancing openness and protection (Henkel, 2006). Given that firms appear to differ in the intensity and form of their community involvement (Lerner and Tirole, 2002), a question of great theoretical and practical importance concerns under what conditions active participation in OSS communities enhances firm performance (Dahlander, 2007; West et al., 2006).

In an effort to address this knowledge gap, the current study examined the relationship between the nature of a firm’s participation in open innovation communities and its innovative and financial performance. Using an original dataset of OSS firms in the Netherlands, I specifically analyze the performance implications of a firm’s technical participation in OSS projects as reflected by its contributions of new software code, bug fixes, and other resources. Based on the idea that community participation may entail both significant benefits and costs (Dahlander and Magnusson, 2005), the main thesis I wish to advance is that firms may face important diminishing returns to increasing levels of involvement in OSS projects and that there exist optimal levels of community participation. This paper tests this idea by empirically examining the presence of a curvilinear relationship between technical community participation and firms’ innovative and financial performance.

A second goal of this study was to shed more light on the boundary conditions under which technical participation in OSS communities improves firm performance. To enhance understanding of how different forms of community participation may reinforce each other, the first contingency factor involved the intensity of a firm’s participation in social, “offline”, activities (e.g., conferences, political campaigns) within the larger OSS community. Previous research has mainly emphasized firms’ technical contributions to OSS projects, arguing that it facilitates access to valuable

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complementary assets (Dahlander and Wallin, 2006). I extend this line of work by arguing that a firm's social community participation influences the degree to which it may capture benefits from technical participation in OSS projects. The distinction between technical and social community participation acknowledges the multidimensionality of the community participation construct (West and Lakhani, 2008) and enables me to identify their unique independent as well as interactive performance effects.

Based on the premise that different types of external linkages are valuable for different types of firms (Peng and Luo, 2000), this research also examines how firm-level characteristics influence the relationship between technical community participation and performance. Given that small and large firms differ in their internal resources and capabilities, I first analyze how firm size moderates the community participation–performance relationship. The role of organizational size is important but far from obvious, because small firms may not only obtain larger benefits from extensive participation in the communities (Gruber and Henkel, 2006) but also incur higher costs. Finally, I examine how a firm's R&D intensity influences the relationship between technical community participation and performance. OSS communities have emerged as an institutional alternative to firm-based innovation (Lee and Cole, 2003), allowing firms to draw from communal resources during the innovation process. Given that there may exist important trade-offs between developing internal technological capabilities and external relationships to the communities (Grand et al., 2004), an important question is whether community participation acts as a substitute or a complement to internal R&D.

2. Theoretical framework and hypotheses

OSS communities exist by virtue of numerous participants who, after having invested private resources in developing new software, freely reveal their proprietary innovations as a public good. As this behavior appears at odds with conventional economic theory (Lerner and Tirole, 2002), a substantial literature has examined the motivations of project contributors. A key insight flowing from this research is that individual contributors may obtain selective private benefits from freely sharing software code that are unavailable to free-riders (Von Hippel and Von Krogh, 2003). These benefits include direct utility from extended functionality (Hertel et al., 2003), increased diffusion (Harhoff et al., 2003), enhanced reputations and career prospects (Lerner and Tirole, 2002), learning and enjoyment (Lakhani and Von Hippel, 2003), and a sense of belonging to a community of like-minded people (Zeitlyn, 2003). Given conditions of low diffusion costs and limited rivalry with potential adopters, these selective benefits explain why programmers continue to freely reveal their innovations (Osterloh and Rota, 2007).

Although the incentives of individual developers to share private resources with the communities are well documented, the motivations of commercial firms appear less straightforward (Henkel, 2006).¹ West and Gallagher (2006) note the existence of a 'paradox' by arguing that commercial firms, unlike individual programmers, face the additional problem that free revealing will benefit their competitors. In reconciling this issue, Osterloh and Rota (2007) discuss two conditions that explain why firms would expose themselves to such risk. First, sharing may provide firms with valuable selective benefits that are unavailable to free-riders (Von Hippel and Von Krogh, 2003). Dahlander and Magnusson (2005) classify these benefits into economic, social, and technological categories. According to this framework, firms devote resources to the commu-

nities because it enables them to lower production costs (Harhoff et al., 2003), enhance the value of complementary assets (Dahlander and Wallin, 2006), improve reputations and public relations (Lerner and Tirole, 2002), signal good OSS citizenship (Henkel, 2006), increase network externalities (West, 2003), and explore new technologies (Osterloh and Rota, 2007). Second, the potential negative impact of sharing may be quite low compared to the expected private gains. The act of revealing source code via the Internet is nearly costless, suggesting that even the prospect of minor benefits is sufficient to induce community participation (Von Hippel and Von Krogh, 2003). Moreover, the risk that a firm's innovations are exploited by competitors is reduced by the availability of OSS licenses and voluntary rule enforcing. OSS licenses guarantee contributing firms that their software remains a public good and hence will not be appropriated by rivals (Osterloh and Rota, 2007). In addition to this legal protection, the commons also employ informal rules to enforce norms of reciprocity (O'Mahony, 2003). Thus, revealing may be a prerequisite for firms to access any communal resources.

Despite the selective benefits and potential low costs associated with community participation, firms commercializing OSS still need to strategically cope with the tension between value creation and appropriation (West, 2003). As noted by Dahlander and Magnusson (2005, p. 484), participating in the communities entails 'a balancing act' in which managers must reconcile requirements of openness and sharing with desires for control and influence. To date, scholars have identified various strategies and business models that firms employ to address these challenges of open innovation (Bonaccorsi et al., 2006; Chesbrough and Appleyard, 2007; Dahlander and Magnusson, 2005; Grand et al., 2004; Henkel, 2006; West and Gallagher, 2006). A core finding in this literature is that although most firms pursue a hybrid approach by combining elements of both openness and protection, the precise balance between the two is driven by firm characteristics. For instance, Henkel (2006) found that firms operating in the embedded Linux market strategically limited their community participation by 'selectively revealing' software code and that the amount of revealing was explained by firm characteristics like size or possession of complementary assets. Overall it appears that different types of firms maintain different levels and forms of involvement in their communities.

But when do these distinct approaches toward community participation actually enhance the innovative and financial performance of OSS firms? Acknowledging the potential value of balancing openness and protection (Laursen and Salter, 2006), the current study addresses this important gap by empirically testing for the presence of decreasing marginal returns to participation in the communities. I distinguish between technical contributions to online OSS projects and participation in social ("offline") community activities and examine whether both forms of involvement have complementary effects on performance. Finally, this paper sheds light on how firm characteristics influence the optimal level of community participation by examining the potential moderating role of firm size and R&D intensity.

2.1. Technical community participation

Technical community participation is defined as the activities firms undertake to make contributions to software development across a variety of OSS projects. It involves activities that are directly or indirectly related to the development of new software such as contributing source code, writing software documentation, and participating in e-mail discussions (Henkel, 2006). Active technical participation in OSS communities implies that firms not only access communal resources to create and appropriate value for their own benefit, but also contribute to community development by shar-

¹ I thank an anonymous reviewer for clarifying the conceptual distinction between the incentives of individual programmers and commercial firms to contribute private resources to OSS communities.

ing source code, technical know-how, and knowledge on end-user requirements with other community members. Compared to firms that view communal resources as a public good that is there for the taking, firms that engage extensively in technical participation realize that a sustainable business model depends on their ability to become actively involved and deeply integrated into the developer community (Weber, 2004).

Firms that participate in OSS projects obtain a number of distinct benefits that are unavailable to companies that make few contributions. Strong ties to the developer communities allow firms to access important complementary assets (Teece, 1986) such as low cost and high quality source code, technological know-how and information on emerging user needs that facilitate the appropriation of rents from internally developed innovations (Dahlander and Wallin, 2006; West, 2003). Firms participating in OSS projects also enhance their visibility in the OSS movement and are more attractive employers for talented programmers (Lerner and Tirole, 2002). Furthermore, community participation can produce valuable first-mover advantages and network externalities that enhance a firm's competitiveness and performance (Dahlander and Magnusson, 2005). By proactively releasing source code to the community, firms may boost the development and adoption of their technologies (Garud et al., 2002) and obtain more influence on the community (Dahlander and Magnusson, 2005). Although such contributions become a public good, the tacit knowledge that firms accumulate through their active involvement in OSS projects constitutes a private benefit that enhances their innovativeness and performance (Grand et al., 2004).

The above arguments have concentrated on the benefits of technical community participation. Yet high levels of community participation also entail important costs, so that firms experience decreasing marginal returns to higher levels of engagement in the communities. Whereas initial increases in firms' participation in OSS projects provide significant learning and legitimacy-building opportunities, increases beyond moderate levels of community participation yield increasingly few additional benefits. As firms intensify their technical activities in OSS projects, they are increasingly exposed to redundant information due to overembeddedness in the communities (cf. Uzzi, 1997). In addition, the communities may perceive firms that make extensive contributions as becoming too influential, so that they are less inclined to provide these firms with access to communal resources (Dahlander and Magnusson, 2005). Establishing and maintaining linkages to the community also requires significant investments of time and people, which are limited in the context of software ventures. Thus at the margin, increasingly high levels of technical community participation may detract firms from managing their core business activities. At the same time, increasing levels of community participation raise project coordination, communication and other transaction costs that eventually outweigh the benefits. Along these lines, Henkel (2006) has noted that contributing software code may result in a loss of strategic resources to competitors and can reduce the firm's control over its further development. In addition, O'Mahony and Bechky (2008) observed that as firms intensify their community participation, they must expend resources in the creation and management of joint institutions that govern firm-community interactions. Thus, whereas too low levels of community participation limits firms' access to value-creating resources, too high levels of community engagement results in excessive transaction costs and loss of resources and control. Based on these arguments, I hypothesize:

Hypothesis 1. Technical community participation has a curvilinear (inverted U-shaped) relationship with (a) the innovative performance and (b) the financial performance of OSS companies.

2.2. The moderating role of social community participation

In addition to technical participation in OSS projects, firms may also participate in the social activities within the larger community. Social community participation is defined as the activities that firms initiate to facilitate knowledge sharing and interactions among developers, firms, end users, and other community members with the purpose to promote the wider acceptance and adoption of OSS (Osterloh and Rota, 2007). Examples of social participation range from organizing workshops and conferences to participating in political and marketing campaigns that are intended to further the interests of the OSS movement. These "offline" activities involve social settings in which individuals from various projects and organizations come together to share knowledge on OSS, construct social networks, and learn about best-practices related to OSS development and commercialization. Firms that exhibit high levels of social community participation recognize that their business prospects are closely connected to the degree to which they play a proactive role in mobilizing collective action among community members (Aldrich and Fiol, 1994).

Firms may capture more benefits from project participation when they also engage in social community participation. Active involvement in OSS projects provides firms with access to valuable technological expertise, yet the value of these resources is contingent on the firm's ability to combine them with knowledge on product markets and user needs into successful new products (Atuahene-Gima and Ko, 2001). Participation in social activities such as industry conferences represents a vehicle through which firms may directly acquire new knowledge on emerging markets, user requirements, and the management of intellectual property rights from entrepreneurs, users, and policy makers that operate in the local market. The face-to-face interactions that occur during such activities facilitate the transfer of tacit knowledge, which is more difficult in the context of computer-mediated relationships (Fowler et al., 2004). Furthermore, the communities perceive firms that are proactively involved in the organization of community activities as more legitimate and are thus more willing to offer them access to valuable communal resources (O'Mahony and Bechky, 2008).

The core *raison d'être* of open source companies, then, can be viewed as their ability to perform a brokering role by connecting OSS communities that develop particular software with potential adopters of these technologies who lack the motivation or ability to directly participate in the communities. Previous research has shown that firms that occupy brokering positions are more innovative and attain higher performance by making new combinations among previously disconnected ideas, actors, and resources (Hargadon, 2002). Thus, firms engaging in both technical and social community participation benefit from the combination of an ability to identify and develop valuable solutions through participation in OSS projects with the capacity to translate and apply these solutions to local market conditions. Thus I hypothesize:

Hypothesis 2. At high levels of technical community participation, the (a) innovative and (b) financial performance is stronger for firms with high levels of social community participation than for firms with low levels of social community participation.

2.3. The moderating role of firm size

The value of community participation not only depends on the balance between performing technical and social activities in the OSS community, but is also determined by firm-level characteristics. An important contingency in this case is firm size. Building on Schumpeter (1942), prior research in industrial economics has advanced arguments as to why large firms may have an advantage in

innovation including their better ability to spread R&D costs, generate economies of scale and scope, attract financial and human capital in imperfect factor markets, build absorptive capacity, and appropriate the returns from innovation due to greater market power (Cohen and Klepper, 1996; Kamien and Schwartz, 1982; Syrnonidis, 1996). On the other hand, others have argued that small firms may have an innovative advantage resulting from a lack of bureaucracy that facilitates speed and flexibility, a niche strategy that enables the commercialization of specialized innovations, and the presence of an entrepreneurial culture that encourages creativity (Acs and Audretsch, 2003; Scherer, 1991). In reconciling these different views, scholars have noted the importance of acknowledging the possibility that the determinants of innovation differ across large and small firms (Acs and Audretsch, 1988; Rogers, 2004).

In line with this reasoning, the current study proposes that the optimal level of participation in OSS projects varies between small and large firms. As small firms have fewer resources available internally, they may initially compensate this by securing access to external resources that are available in OSS communities. Indeed, scholars have noted the importance of external linkages for small firms (Rogers, 2004). Thus at low to moderate levels of technical community participation, the marginal benefits of participation should be greater for small firms. At the same time, however, firm size also indicates the degree to which a firm has sufficient resources to support high levels of community participation. Large firms have more financial and human resources that can be used to set up new OSS projects, coordinate existing projects, and sponsor community activities. For small firms, above-average levels of community involvement quickly increase marginal costs as critical resources necessary for the firm's core activities are diverted to community activities. By contrast, larger firms have the resources to implement a dedicated organizational unit that manages community relationships (cf. Kale et al., 2002). Thus larger firms are better positioned to appropriate the returns from community-based innovations due to their stronger absorptive capacity and market power (Belderbos et al., 2004). In sum, small firms obtain lower marginal benefits and incur higher marginal costs from high levels of community participation compared to large firms. This logic suggests:

Hypothesis 3. At high levels of technical community participation, the (a) innovative and (b) financial performance is stronger for large firms than small firms.

2.4. The moderating role of internal R&D intensity

Although technical participation in OSS communities facilitates access to complementary assets and technological know-how, previous research has suggested that the value of external collaboration is contingent on a firm's capacity to absorb, assimilate, and apply knowledge sourced from outside firm boundaries (Chesbrough et al., 2006; Cohen and Levinthal, 1990; Veugelers, 1997). Prolonged investments in R&D result in an absorptive capacity that leverages a firm's ability to appropriate value from the publicly available knowledge developed by OSS communities (Fosfuri et al., 2008). Firms with a strong knowledge base are in a better position to generate unique configurations of internal and external resources, which support their capacity to generate and appropriate returns from innovations (Dahlander and Wallin, 2006; Grand et al., 2004). The presence of such "complementarities" (Veugelers, 1997) thus suggests that a firm's access to community resources is conditioned by its internal R&D activities. As firms with technological know-how can make more valuable contributions to the communities, they are also more likely to obtain valuable resources in return that contribute to higher performance. Greater community participation in turn also enhances the productivity of the firm's internal R&D by securing access to complementary knowledge

assets (Fosfuri et al., 2008). Firms that are extensively involved in OSS communities have privileged access to information on promising market opportunities that support the allocation of internal R&D resources to more rewarding business activities (Veugelers, 1997). These arguments support the following hypotheses:

Hypothesis 4. At high levels of technical community participation, the (a) innovative and (b) financial performance is stronger for firms with high R&D intensity than firms with low R&D intensity.

3. Methods

3.1. Sample and data collection

The hypotheses were tested using an original dataset of firms commercializing OSS in the Netherlands. OSS firms were defined as firms that sell products and services that are based on OSS, i.e. software incorporating an OSS license. Similar to prior studies in Italy (Bonaccorsi et al., 2006) and Scandinavia (Dahlander and Magnusson, 2005), the Dutch software market has recently witnessed the emergence of many small firms that entered the market by offering OSS products and/or complementary services. Data was gathered in 2005 through a survey that was administered with each firm's top management team.

In the absence of a complete overview of all firms in the Dutch OSS industry, I addressed the importance of adequately identifying the complete study population by following a two-step approach (cf. Stam and Elfring, 2008). First, I used several secondary data sources to construct an initial list of firms. Relevant sources included (1) the membership list of the industry association "Vereniging Open Source Nederland," (2) the website of the governmental program "Open Standards and Open Source Software" that contained a list of OSS companies, and (3) Internet searches by means of keywords such as "open source solutions," "open source services," and "Linux solutions." In total this search yielded 127 firms. Next, in the second step I conducted interviews with key informants knowledgeable about the industry to validate the initial list. Nine ventures were mentioned by more than one expert and were added to the initial list, yielding 136 firms in total. Since 11 ventures turned out to have gone out of business or had ceased their OSS activities, the final study population amounted to 125 firms.

After using the interviews with key informants as input for questionnaire construction, I first pre-tested the questionnaire on six representative firms. I followed several suggestions by Dillman (2000) in order to maximize response rates. Firms were sent a letter stating the purpose and importance of the research project, followed by a phone call in which they were requested to participate. Whenever possible, appointments were made during which the questionnaires were personally delivered to the entrepreneurs. In total I received 121 individual responses from 90 firms, representing an overall participation rate of 72 percent. An average of 1.36 individuals (a 62 percent internal response rate) responded from each firm. I tested for nonresponse bias by comparing key attributes of respondents to those of nonrespondents. For the variables of both firm size (as total number of employees) and firm age (as number of years since firm formation) *t*-tests indicated no significant differences.

3.2. Measures and validation

3.2.1. Innovative performance

A variety of empirical indicators of innovative performance exists in the literature, ranging from R&D expenditures and patent counts to new product announcements (Hagedoorn and Cloodt, 2003). Since each of these measures has important merits and drawbacks (Kleinknecht et al., 2002), the choice for a specific indi-

cator depends on the goals and context of the research in question. In the current study, I focused on how different innovation inputs (i.e., community participation and organizational resources) shape the innovative output of OSS companies. Thus, indicators related to patents and innovation expenditures were inappropriate to capture the innovative performance of firms in this study.

A more adequate measure of innovative performance, then, was a count of the number of new products introduced by a given firm. This constitutes a more direct measure of a firm's innovation output and has been successfully used in previous research (Kleinknecht et al., 2002). In line with prior work using the definitions of the Community Innovation Survey (CIS), I defined new product introductions as new or significantly improved products and services that were introduced during the last year and that were not only new to the firm, but also to the market (i.e., not previously introduced by competitors). To validate this measure, I used Covin and Slevin (1989) three-item innovativeness scale ($\alpha = 0.74$), which has been frequently used in prior work (Adams et al., 2006). A significant positive correlation of the two measures ($r = .38, p < .01$) provided support for the validity of the new product introductions measure.

3.2.2. Financial performance

Although there is no generally accepted approach in measuring the performance of small firms, researchers commonly use indicators of financial performance and firm growth (Chandler and Hanks, 1993). Objective performance data, however, are generally often unavailable and may be difficult to interpret in the context of small firms. Given that performance evaluations compared with competitors have been found to exhibit high levels of reliability and validity (Dess and Robinson, 1984), I used self-reported measures of firms' financial performance relative to competitors: sales growth, market share, gross profits, and net profit margin. A seven-point Likert scale was employed ranging from "much worse" to "much better" ($\alpha = 0.89$). To validate this subjective measure, I successfully obtained objective sales growth data on a subsample of 72 firms and found that the subjective performance measure was significantly correlated with ventures' sales growth over the past year ($r = .37, p < .01$).

3.2.3. Community participation

Given my interest in the performance implications of community participation, respondents were asked to indicate the extent to which their firms had performed a variety of activities in the OS community. I used a five-point Likert scale with individually labeled answer categories ranging from "never" to "very often." In all cases, very often was coded as 5.0 while never was coded as 1.0 (i.e., larger values denote greater participation). Eleven items were included that were identified from previous empirical research (e.g., Bonaccorsi et al., 2006; Ghosh and Glott, 2005; Von Krogh et al., 2003) and conceptual work (e.g., Feller and Fitzgerald, 2002).

Table 1 presents the items that were used and the results of a principal-components analysis that was performed to assess any interrelationships among the different activities and to look if these could be reduced to a smaller number of dimensions. A varimax rotation was performed on all factors satisfying Kaiser's criterion (i.e., eigenvalues of 1.0 or greater). This procedure produced two factors explaining 58.02% of the total variance. All items showed strong factor loadings of 0.69 or higher and cross-loadings below 0.30. Given the commonly used cut-off point of 0.30, the factor loadings demonstrated strong significance and were representative of the underlying components (Kim and Mueller, 1978).

My conclusion from this analysis is that I have empirically isolated two factors that represent important, yet distinct dimensions of community participation by commercial firms. The first factor consisted of six items and was labeled *technical community partic-*

ipation ($\alpha = 0.87$); the second factor was made up of five items and labeled *social community participation* ($\alpha = 0.77$). Both constructs were moderately correlated ($r = .29, p < .01$), suggesting that they captured unique variance in firms' community participation.

Following Carmines and Zeller (1979), I verified the validity of both measures by assessing their correlations with other empirical indicators of community participation. The measure of technical community participation was significantly correlated with the number of OSS projects initiated by the firm ($r = .48, p < .001$) and the number of OSS projects in which the firm was participating ($r = .60, p < .001$). As for my measure of social community participation, I constructed an overview of all conferences, seminars, and meetings that had taken place in the industry over the last five years and counted the number of events in which each firm had participated. The correlation between this measure and the social community participation measure was positive and significant ($r = .40, p < .001$).

3.2.4. R&D intensity

To capture a firm's prolonged investments in R&D, previous research on large firms has often used a firm's patent portfolio as an indicator of its absorptive capacity (Cohen and Levinthal, 1990). In the current research, however, patents were not a good indicator of internal R&D since it examines relatively young and small firms that commercialize OSS and possessed few patents. I therefore built on previous work on new technology ventures (e.g., Rothaermel and Thursby, 2005) by using data on firms' resource allocations to innovative activities. Respondents were requested to estimate the share of total R&D expenditures in previous year's total sales (*R&D intensity*). To validate this measure, I also computed the percentage of the firm's total employees that were involved in developing new products and services. Both measures were significantly positively correlated ($r = .52, p < .01$) and yielded similar results.

3.2.5. Control variables

Previous research has shown that younger and smaller firms face more severe challenges in exploiting technological opportunities compared to established firms because of their limited resources and legitimacy (Freeman et al., 1983). I therefore controlled for *firm age* by calculating the logarithm of the number of years since firm founding. *Firm size* was calculated as the logarithm of the total number of employees including founders (full-time equivalents). Next, the extent to which firms pursue a pure open source business model may reflect variation in benefits and costs associated with community participation. I therefore controlled for *OSS specialization* by including the percentage of firms' total revenues over the past year that was generated from OSS. Furthermore, to ensure that the technical community participation measure captured project contributions rather than just the number of projects in which firms were involved, I controlled for the latter (*OSS projects*). Finally, I controlled for the percentage of total OSS projects that were initiated by the focal firm (*self-initiated OS projects*), given that such projects may entail distinct costs and benefits.

3.3. Assessing common method bias

I undertook several steps to evaluate and reduce the potential for common method bias in the current study (Podsakoff et al., 2003). First, I assessed interrater reliabilities for the 26 firms where I obtained data from multiple respondents. Intraclass correlation coefficients (ICC [1,1]) for the scales exhibited high interrater reliability (Shrout and Fleiss, 1979): innovative performance (ICC = .67), financial performance (ICC = .76), technical community participation (ICC = .64), and social community participation (ICC = .71). Second, I performed a Harman's one-factor test across sets of items used to measure the financial performance and community participation constructs. Three distinct factors were extracted that

Table 1
Principal component analysis results.

	Mean	S.D.	Alpha	% Total variance explained	Item loadings	Corrected item-total correlation
Technical community participation	2.89	0.89	0.87	33.73		
Contributing code, bug fixes, and patches to open source projects	3.22	1.15			0.83	0.74
Writing software documentation for open source projects	2.42	1.08			0.82	0.72
Performing a coordinating function within open source projects (e.g., committer)	2.54	1.34			0.77	0.67
Translating software or documentation for open source projects	2.56	1.25			0.75	0.63
Providing ideas and suggestions for new software features to open source projects	3.17	1.08			0.75	0.68
Participating in discussions on mailing lists and discussion forums	3.52	1.08			0.69	0.61
Social community participation	2.78	0.73	0.77	24.29		
Organizing workshops, conferences, and other events related to open source software	2.42	1.06			0.74	0.57
Financial sponsoring of events and activities related to open source software	2.40	0.87			0.74	0.58
Undertaking activities to raise public awareness for open source software	3.29	1.13			0.73	0.51
Participating in political activities (e.g., against software patents)	2.60	1.17			0.69	0.51
Participating in workshops, conferences, and other events related to open source software	3.17	0.78			0.69	0.56

accounted for 69.37 percent of the total variance, with the first factor explaining 22.47 percent of the variance. Thus neither a single factor emerged, nor did one factor account for the majority of the variance. Finally, I followed the suggestions offered by Podsakoff et al. (2003) and performed confirmatory factor analyses (CFA). Three models were evaluated: (1) a model loading all items onto a common method factor, (2) a model loading the items onto their theoretically assigned latent variables, and (3) a model loading the items onto their latent variables as well as on an additional method factor. In all cases, a two-factor model yielded a superior fit to the data. Although method variance cannot be ruled out completely, these results suggest it was not a major problem.

3.4. Analytical approach

I used hierarchical moderated regression analysis to test the hypotheses. This approach is appropriate for interactions among the variables of interest (Cohen and Cohen, 1983). Hierarchical regression analysis allows for a comparison between alternative models with and without interaction terms, where an interaction effect only exists if the interaction term contributes significantly to the variance explained in the dependent variable over the main effects of the independent variables (Jaccard and Turrisi, 2003). Following Aiken and West (1991), I mean-centered the independent variables prior to the formation of interaction terms in order to reduce potential multicollinearity concerns and enhance the interpretation of the results. For all models I checked the variance inflation factors (VIF) values and found no severe signs of multicollinearity (largest VIF = 3.08).

Since the two dependent variables in this study, innovative performance and financial performance, had distinct statistical properties I used two different statistical estimation procedures. In the case of financial performance, I employed ordinary least squares (OLS) regression analysis since all assumptions of the OLS model were satisfied. As for innovative performance, I employed a count of the number of new product introductions. Since count outcomes constitute non-negative integer values that are characterized by significant skewness and heteroskedasticity, the use of OLS regression was inappropriate (Cameron and Trivedi, 1998). Instead, I employed a negative binomial regression model, which is a particular case of the Poisson regression model. The negative binomial model was preferred to a Poisson estimation since the data were characterized by overdispersion. That is, the variance exceeded the mean of the event count (Cameron and Trivedi, 1998).

4. Results

4.1. Sample characteristics and open source business models

Table 2 presents some descriptive statistics of the sample firms. The industry was still emerging, with many young and small companies that were technically oriented. A typical firm had been in business for only five years, was founded by two entrepreneurs, and employed in total about six persons. These firms were managed by teams of entrepreneurs who already had more than twelve years of work experience in the information technology industry, but who had limited experience in the area of marketing and sales. Similarly, a significant share of firms' staff had a technical orientation with more than half of the staff consisting of product developers. These findings are consistent with prior research showing that high-technology firms generally have a strong technical background and often lack sufficient marketing expertise that is necessary to successfully commercialize innovations (Roberts, 1991). In contrast to a study of Italian OSS firms by Bonaccorsi and Rossi (2006), which reported that only very few employees were

Table 2
Descriptive statistics of sample firms.

	Mean	S.D.	Min.	Max.
Firm age	5.24	4.18	0.50	29.25
Firm size	5.87	8.27	1	50
Founding team IT industry experience ^a	12.18	10.91	0	60
Founding team marketing and sales experience ^a	2.68	5.00	0	24
Sales growth in 2004	61.70	77.54	-20	300
New product introductions ("new to the market")	1.50	2.04	0	15
Sales of "new to the market" products and services ^c	0.28	0.32	0	1.00
Staff with university degree ^b	0.40	0.37	0	1.00
New product developers ^b	0.53	0.40	0	1.00
R&D intensity ^c	0.28	0.28	0	1.50
OSS specialization ^c	0.72	0.33	0.05	1.00
Government and non-profit sales ^c	0.26	0.28	0	0.99
SME sales ^c	0.43	0.35	0	1.00
Foreign sales ^c	0.04	0.09	0	0.50
Number of OSS projects participated	3.28	4.02	0	16
Number of OSS projects self-initiated	1.07	2.39	0	16

^a Measured as the team's total number of years of work experience at time of firm formation.

^b Taken as a proportion of total staff.

^c Computed as a percentage of total sales in 2004.

Table 3
Means, standard deviations, and correlations.^a

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Innovative performance	3.14	7.73									
2. Financial performance	4.20	1.18	.17								
3. Technical participation	2.89	0.89	.19	.16							
4. Social participation	2.78	0.73	.04	.05	.29**						
5. R&D intensity	0.28	0.28	.29**	-.15	.27*	-.02					
6. Firm age ^b	0.58	0.39	-.12	-.02	-.03	.03	-.28*				
7. Firm size ^b	0.61	0.33	-.08	.35**	.21	.06	-.02	.37**			
8. OSS specialization	0.72	0.33	.20	-.12	.20	.12	.24*	-.10	-.19		
9. OSS projects	3.28	4.02	-.04	.30**	.35**	.14	-.08	.16	.33**	-.01	
10. Self-initiated OSS projects	0.22	0.31	-.07	.11	.30**	.01	.16	-.10	.07	.12	.30**

^a N = 90.

^b Log transformed.

* p < .05.

** p < .01 (two-tailed).

university graduates, over 40 percent of the sample firms' staff had in fact a university degree. This result supports earlier research that has demonstrated that developers are generally highly educated and confirms studies showing that high-technology firms employ more educated staff compared to less knowledge-intensive firms (Roberts, 1991).

With regard to firms' engagement in OSS projects, the data show that the average firm was involved in about three projects of which one project had been started by the firm itself. This finding complements Dahlander (2007), who suggested that firms may either initiate new or rely on existing communities, by showing that firms *both* joined existing projects and initiated new projects. As shown in Table 2, Dutch OSS firms mainly pursued hybrid business models. Similar to the Italian case (Bonaccorsi et al., 2006), sample firms generated most revenues from OSS solutions but also had traditional proprietary offerings. Interviews with the entrepreneurs suggested that many customers were still unaware of OSS or perceived it as a risky alternative and as a consequence, many firms were more or less "forced" to also offer proprietary solutions. With regard to product offerings, I found that most firms sold few hardware solutions. Sales of a typical firm were based for about 41

percent on software development, while over 52 percent of revenues came from offering additional services such as consultancy, support, and training.

With respect to the distribution of firms' sales over three main customer groups, the data show that small and medium-sized enterprises (SMEs) accounted for the largest proportion of sales (43%), followed by large firms (31%) and government and nonprofit organizations (26%). Given the fragmented nature of the SME market and the general tendency for governments and large firms to be early adopters of OSS, this finding is quite surprising. Finally, the limited share of sales to foreign clients (4%) suggests that most firms predominantly focused on serving the Dutch market. This finding is consistent with the observation that most firms relied on service revenues, which are often tailored and sold to customers in the local market.

4.2. Hypothesis tests

I tested the hypotheses using moderated hierarchical regression analysis. Separate models were estimated for financial and innovative performance. Table 3 presents the correlations among the

Table 4
Results of negative binomial regression predicting innovative performance.^a

Variables	Innovative performance				
	Model 1	Model 2	Model 3	Model 4	Model 5
<i>Step 1: controls</i>					
Constant	0.825*** (0.136)	1.026*** (0.159)	0.755*** (0.138)	0.762*** (0.146)	0.519*** (0.157)
Firm age	-0.033 (0.031)	-0.040 (0.031)	-0.022 (0.030)	-0.040 (0.031)	-0.033 (0.030)
Firm size	-0.016 (0.024)	-0.015 (0.022)	-0.017 (0.022)	-0.015 (0.035)	-0.013 (0.022)
OSS specialization	1.191** (0.483)	1.204* (0.470)	1.221** (0.464)	1.244** (0.474)	1.264** (0.465)
R&D intensity	1.83*** (0.480)	1.683** (-0.539)	1.528** (0.509)	1.680** (0.531)	1.041† (0.557)
OSS projects	0.021 (0.042)	-0.010 (0.041)	-0.021 (0.039)	-0.010 (0.042)	-0.022 (0.040)
Self-initiated OSS projects	-0.872† (0.483)	-0.788† (0.479)	-0.645 (0.464)	-0.755 (0.482)	-0.357 (0.481)
Social participation	0.039 (0.195)	.018 (0.188)	0.080 (0.200)	0.015 (0.229)	0.064 (0.181)
<i>Step 2: main effects</i>					
Technical participation		.280 (0.203)	0.407* (0.205)	0.254 (0.230)	0.372† (0.201)
Technical participation squared		-.341** (0.139)	-0.491** (0.159)	-0.331* (0.150)	-0.666** (0.211)
<i>Step 3: moderating effects</i>					
Technical participation × social participation			-0.335 (0.253)		
Technical participation squared × social participation			0.771** (0.285)		
Technical participation × firm size				-0.022 (0.046)	
Technical participation squared × firm size				-0.022 (0.046)	
Technical participation × R&D intensity					2.220** (0.790)
Technical participation squared × R&D intensity					-0.760† (0.396)
Overdispersion parameter	0.88***	.75***	0.62***	0.74***	0.66***
Log likelihood	-166.67	-163.39	-156.82	-163.04	-159.45

^a Unstandardized coefficients are reported with standard errors in parentheses.

† p < .10.

* p < .05.

** p < .01.

*** p < .001.

Table 5
Results of OLS regression predicting financial performance.^a

Variables	Financial performance				
	Model 1	Model 2	Model 3	Model 4	Model 5
<i>Step 1: controls</i>					
Constant	4.265*** (0.460)	4.576*** (0.161)	4.319*** (0.129)	4.359*** (0.123)	4.142*** (0.134)
Firm age	-0.031 (0.043)	-0.021 (0.041)	-0.005 (0.040)	-0.047 (0.042)	-0.010 (0.040)
Firm size	0.034* (0.017)	0.032† (0.017)	0.033* (0.016)	0.081*** (0.025)	0.029† (0.016)
OSS specialization	-0.307 (0.453)	-0.248 (0.431)	-0.208 (0.427)	-0.121 (0.420)	-0.073 (0.423)
R&D intensity	-0.251 (0.457)	-0.281 (0.483)	-0.380 (0.479)	-0.421 (0.469)	-0.770 (0.510)
OSS projects	0.055 (0.040)	0.015 (0.041)	0.018 (0.040)	0.026 (0.040)	0.018 (0.040)
Self-initiated OSS projects	0.391 (0.459)	0.387 (0.443)	0.384 (0.430)	0.347 (0.427)	0.670 (0.451)
Social participation	-0.002 (0.172)	-0.126 (0.171)	0.003 (0.178)	-0.100 (0.165)	-0.116 (0.167)
<i>Step 2: main effects</i>					
Technical participation		0.283 (0.177)	0.225 (0.175)	0.154 (0.183)	0.221 (0.190)
Technical participation squared		-0.372** (0.127)	-0.322** (0.126)	-0.265* (0.130)	-0.627*** (0.161)
<i>Step 3: moderating effects</i>					
Technical participation × social participation			0.176 (0.227)		
Technical participation squared × social participation			0.564* (0.227)		
Technical participation × firm size				-0.021 (0.034)	
Technical participation squared × firm size				0.080* (0.034)	
Technical participation × R&D intensity					1.211† (0.651)
Technical participation squared × R&D intensity					0.065 (0.374)
R ²	0.146	0.252	0.318	0.326	0.320
Adj. R ²	0.058	0.150	0.201	0.211	0.203
F	1.657	2.471*	2.711**	2.818**	2.736**

^a Unstandardized coefficients are reported with standard errors in parentheses.
 † $p < .10$.
 * $p < .05$.
 ** $p < .01$.
 *** $p < .001$.

variables included in the statistical analyses. In Table 4, I report the results of negative binomial regression analyses predicting firms' innovative performance. The results of OLS regression analyses predicting firms' financial performance are presented in Table 5. Model 1 constitutes the baseline model with only the control variables. Next, model 2 adds the main effects of technical community participation by including its linear and quadratic terms to test hypotheses 1a and 1b. Finally, models 3–5 add the interaction terms between the linear and quadratic terms of technical community participation and each of the three moderator variables to test the interaction hypotheses. Given my moderate sample size and significant correlations among the interaction terms, I chose to estimate separate models for testing each hypothesis.

Hypotheses 1a and 1b postulate an inverted U-shaped relationship between technical community participation and the innovative performance and financial performance of OSS companies, respectively. Model 2 in Tables 4 and 5 presents the empirical results for the two dependent variables. Consistent with the hypotheses, the results show that the quadratic term of technical community participation is negative and statistically significant ($b_{innovative\ performance} = -0.341, p < .01$; $b_{financial\ performance} = -0.372, p < .01$). Thus, hypotheses 1a and 1b were supported.

Next, hypotheses 2a and 2b propose that social community participation positively moderates the relationship between technical community participation and firms' innovative and financial performance. As shown in model 3 of Tables 4 and 5, the quadratic by linear interaction of technical and social community participation is positive and statistically significant ($b_{innovative\ performance} = 0.771, p < .01$; $b_{financial\ performance} = 0.564, p < .05$).

To further our understanding of this interaction effect, Fig. 1 presents a graphical representation of the relationship between technical community participation and performance using the procedures outlined by Aiken and West (1991). The graph confirms that technical community participation is more strongly associated with performance when firms also exhibit high levels of social community participation. Thus, hypotheses 2a and 2b were supported.

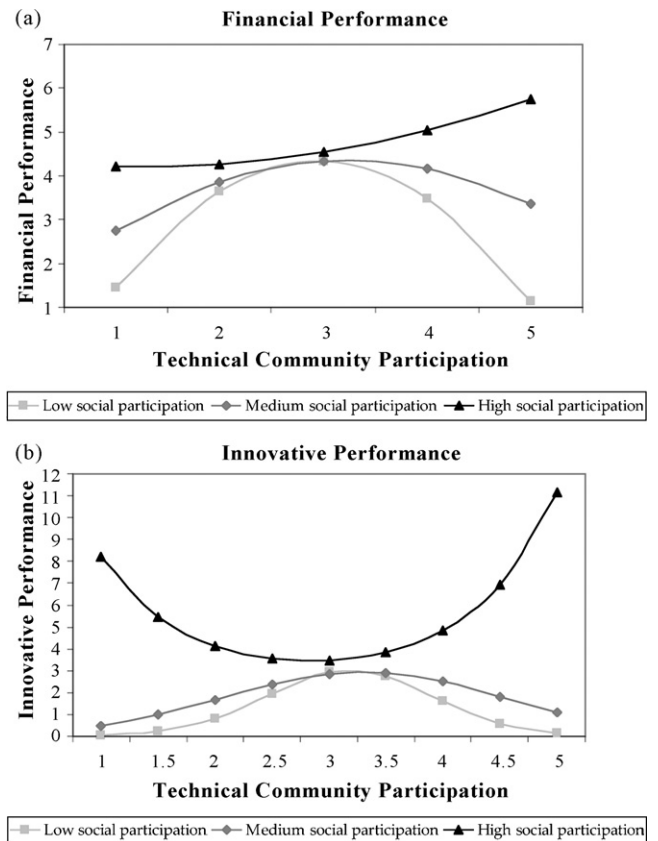


Fig. 1. Technical and social community participation interaction. (a) Financial performance and (b) innovative performance.

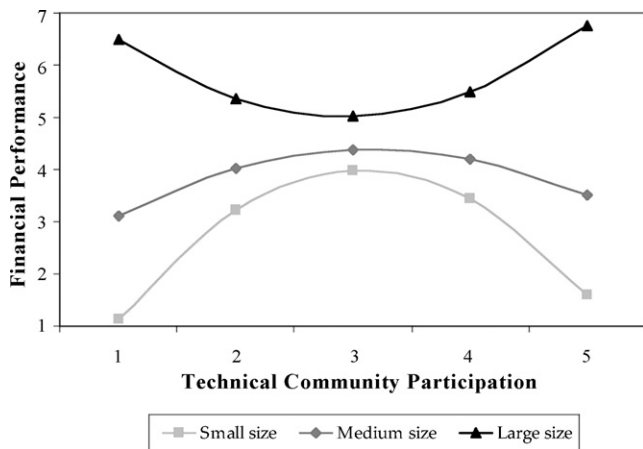


Fig. 2. Technical participation and firm size interaction.

Next, hypotheses 3a and 3b postulate that firm size positively moderates the relationship between technical community participation and both dependent variables. Contrary to hypothesis 3a, the results in model 4 of Table 4 reveal that the quadratic by linear interactive effect of technical community participation and firm size on innovative performance is negative and not significant ($b_{\text{innovative performance}} = -0.022$, n.s.). As for financial performance, the interaction between technical community participation and firm size is positive and significant ($b_{\text{financial performance}} = 0.08$, $p < .05$). Fig. 2 reveals that at high levels of technical community participation, larger firms demonstrate higher financial performance than small firms. Thus, hypothesis 3a received no support and hypothesis 3b was supported.

Finally, hypotheses 4a and 4b stipulate that a firm's internal R&D intensity positively moderates the relationship between technical community participation and the firm's innovative and financial performance. Consistent with hypothesis 4a, model 5 of Table 4 shows that the linear by linear interaction between technical community participation and R&D intensity is positive and significant ($b_{\text{innovative performance}} = 2.220$, $p < .01$). Next, model 5 of Table 5 reveals that the interaction effect for financial performance was positive, but marginally significant ($b_{\text{financial performance}} = 1.211$, $p < .10$). For both models, the quadratic by linear interaction was not statistically significant. Fig. 3 graphically shows that a firm's internal R&D intensity strengthens the relationship between technical community participation and its innovative performance. Thus, hypothesis 4a was supported and hypothesis 4b received weak support.

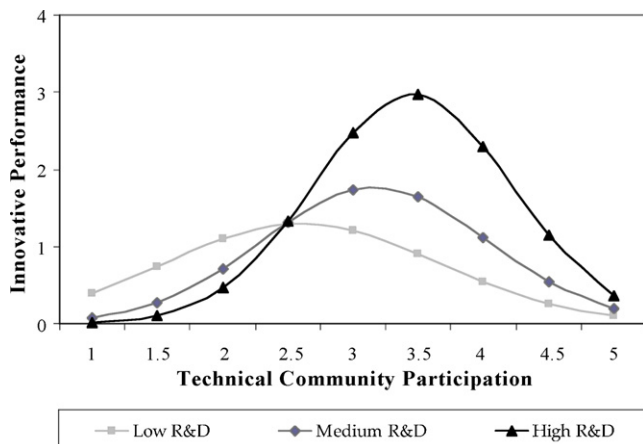


Fig. 3. Technical participation and internal R&D intensity interaction.

5. Discussion

The goal of this research was to empirically examine under what conditions participation in open innovation communities strengthens the innovative and financial performance of software firms that pursue an open business model. Using an original dataset of OSS companies in the Netherlands, the current study presents initial empirical evidence supporting the theoretical notion that firms may obtain important private rewards from making contributions to the community. In particular, I found that the association between technical community participation and performance is nonlinear, indicating the presence of important decreasing marginal returns to higher levels of involvement in OSS projects. To increase understanding of the boundary conditions under which this relationship holds, I also examined several contingencies that influence the relationship between technical community participation and performance. This analysis revealed that participation is more strongly related to performance for firms that also exhibit high levels of social participation, for firms of larger size, and for firms with high R&D intensities. The theoretical and practical implications of these findings are discussed next, along with the limitations of the study and suggestions for future research.

5.1. Theoretical implications

The results support recent theoretical contentions that open innovation communities produce complementary assets that are of significant value to OSS firms (Bonaccorsi et al., 2006; Dahlander and Wallin, 2006). In particular, the findings confirm Von Hippel and Von Krogh (2003) argument that active contributors to the community obtain private rewards that are unavailable to free-riders. Yet this research extends this line of work by revealing the presence of important diminishing returns to community participation, thus indicating that there exist optimal levels of engagement in the community. Community participation had a positive, and then a negative association with performance. It appears that firms may engage in too much community interaction and become overembedded in the OSS community. In support of O'Mahony and Bechky (2008) finding that participating firms also need to engage in the design and management of community institutions, the current study shows that contributing to OSS projects not only yields benefits but also entails significant costs in terms of resource investments and loss of strategic assets that may result in decreasing returns. Recognition of this nonlinear relationship is important, because it underscores the complexity of the community participation–performance link and highlights the difficulties that are associated with appropriating value from open innovation (Chesbrough et al., 2006).

This research also contributes to the small, but growing literature on firm–community interactions (Dahlander and Magnusson, 2005; West and Gallagher, 2006) by illustrating the importance of taking a multidimensional perspective on community participation. I differentiated between technical activities like contributing software code and bug fixes, and social activities such as organizing conferences and mobilizing the community to stimulate public awareness and support for OSS. Although prior studies have mainly emphasized the former, I found that achieving a balance between technical and social participation in the OSS community is positively related to performance. In particular, the results indicate that a high level of technical participation is negatively related to performance at low levels of social participation, but has a positive relationship with performance at high levels of social participation. These findings highlight the presence of complementarities between the different types of activities that firms may perform in the community and suggest that in addition to establishing a strong online presence, firms must also consider their “offline activities”

in the OSS community. These activities provide firms with the tacit knowledge that is difficult to transfer in computer-mediated relationships (Fowler et al., 2004) and may address some of the tensions that arise in firm–community interactions (O'Mahony and Bechky, 2008).

My analysis of moderating relationships also uncovered important firm-level contingencies that condition the performance impact of community participation. The positive interaction effect between technical community participation and firm size on firms' financial performance reveals both the opportunities and limits of community participation for small OSS firms. On the one hand, the result highlights that for small firms, initial increases in involvement in the communities has a positive impact on their financial performance. This result is consistent with previous arguments that small firms have a limited resource base and therefore have relatively more to gain from external relationships (Rogers, 2004). Such relations represent conduits of valuable resources that allow small firms to appropriate more value from their innovations (Teece, 1986). At the same time, however, the findings show that above-average levels of technical community participation limit the financial performance of small OSS firms. In line with recent contentions that successful participation in OSS communities requires significant investments of organizational resources (Grand et al., 2004), the results suggest that the limited resource base of small firms exerts a "ceiling-effect" on the optimal level of community involvement.

The finding of a positive interaction between technical community participation and R&D intensity on firms' innovative and financial performance supports the view that internal and external sources of innovation are complements rather than substitutes (Veugelers, 1997). Although the communities are seemingly open to any firm interested in joining them, the results suggest that internal R&D enables firms to appropriate a larger part of the value that is created in OSS projects (Teece, 1986). Firms with strong technical know-how have the absorptive capacity to recognize, assimilate, and apply the knowledge resources that are available in the communities (Cohen and Levinthal, 1990). Similarly, community engagement stimulates the discovery of new opportunities that may redirect a firm's internal R&D towards more lucrative business activities.

5.2. *Limitations and future research*

The contributions of this study must be viewed against some limitations. First, data collection through surveys may have introduced common method bias. I took several steps to address this potential problem, including the use of multiple measures, secondary respondents, and Harman's one factor test. Although these procedures suggested few problems, future research should aim to collect objective data on firms' community participation from online repositories such as SourceForge.

Second, future research should expand the range of performance outcomes studied. The current study's focus on explorative innovations raises the question how community participation influences other types of innovation performance such as exploitative innovations. In addition, while this study only considered short-term financial and innovation performance outcomes, firms may actually have very different motivations to participate in the communities, ranging from serving pure economic interests to the pursuit of social and political goals (Weber, 2004). Thus, an interesting area of inquiry is contrasting the immediate and delayed effects of community participation on other relevant outcomes such as customer satisfaction or attracting talented programmers.

Third, this study examined only a single industry. Although the software industry is at the forefront of adopting open business models, other industries are also witnessing the emergence

of open innovation (Chesbrough et al., 2006). Thus, future studies may examine community participation by firms in other sectors such as biotechnology and multimedia. This line of work should also compare the performance effects of community participation between firms pursuing different business models. Recent research suggests that companies may employ a variety of commercialization strategies to profit from OSS including open versus hybrid models (Bonaccorsi et al., 2006), initiating new versus joining existing communities (Dahlander, 2007), and complete versus selective revealing of source code (Henkel, 2006). Future research is encouraged to examine how different configurations of business models and forms of community participation affect a firm's performance outcomes.

Fourth, a limitation of this study's research design is the potential for endogeneity and reverse causality. Endogeneity may be present because prior research has shown that there are two-way relationships between a firm's internal R&D expenditures and external R&D activities (Veugelers, 1997) as well as among a firm's size and R&D intensity (Belderbos et al., 2004). Reverse causality may stem from the possibility that a firm's performance impacts its subsequent size and R&D activities (Syneonidis, 1996). Although the data underlying the current study did not allow controlling for this simultaneity, future studies on the consequences of a firm's community participation should account for these alternative explanations.

Fifth, by focusing at the firm-level, this research has ignored the question how community participation by commercial firms influences the emergence, growth, and decline of these communities. Observing a curvilinear relationship between community participation and firm performance raises the question whether initial benefits of participation for the firm represent a loss to the community. Similarly, negative returns to high levels of participation may reflect positive returns to the community. Future research can make a valuable contribution by assessing when community participation by firms enhances both firm and community performance.

Finally, while this study presented community participation as an important alternative to interfirm collaboration, it did not empirically compare the performance effects of these linkages. A promising line of research involves studying whether both types of relationships are complementary and if they require similar or distinct management structures. Although the alliance literature has identified various components of a firm's alliance capability (Kale et al., 2000), managing relationships with the communities may pose distinct managerial challenges (Dahlander and Magnusson, 2005). Thus, future studies should examine why certain firms are better at forging links to OSS communities and extracting value from such relationships. An important question in this regard is how firms may leverage their interests by participating in the design and management of community institutions (cf. O'Mahony and Bechky, 2008).

5.3. *Practical implications*

Notwithstanding the above limitations, this research offers some important practical implications for entrepreneurs and managers who are interested in pursuing an open innovation strategy. The findings indicate that managers may enhance the innovativeness and financial performance of their firms by stimulating their employees to become more involved in OSS communities. Instead of free-riding on the community, firms should consider the learning and resource advantages associated with contributing back to the community. At the same time, however, managers must recognize the presence of decreasing returns to community participation and achieve an appropriate balance between the technical and social activities that their firms perform in the OSS community. Although community participation may facilitate firm performance, man-

agers must acknowledge the contingent nature of this relationship. This study supports the notion that different types of firms require different levels of technical community participation. Accordingly, managers may enhance firm performance by creating a fit between the nature of their firm's involvement in the communities and its internal resources and capabilities. In particular, small software firms benefit most from relatively low to moderate levels of community participation due to their limited internal resource base. The results also demonstrate that participation in the OSS community acts as a complement rather than a substitute to internal technological know-how. Thus, managers are encouraged to simultaneously invest in internal R&D and external linkages to OSS communities.

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