MASTER

A breeding ground for innovation
peer-to-peer assistance in the hybrid model of innovation

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A breeding ground for innovation: peer-to-peer assistance in the hybrid model of innovation

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In partial fulfilment of the requirements for the degree of master of science in innovation management

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ABSTRACT

The hybrid innovation model balances on the nexus of proprietary and open source development. Aiming to determine how this striking joining of forces by financially driven corporations and intrinsically driven individuals can best be explained, the present study pays particular attention to the motives that underpin software developers’ rationale for joining such ‘gated’ open source projects.

Drawing upon social network analysis of the Stackoverflow.com community, archival data of the website at hand and, finally, a survey among a random sample of its members, the present study 1) introduces a new model of software developers’ motives for contributing to hybrid innovation efforts, and 2) seeks to find whether significant differences exist between developers’ rationale for joining ‘full’ and gated open source projects.

PLS analysis revealed that tenure in the field, commitment towards the platform at hand, social embeddedness in the development community, kinship with the open source ideology and finally the incremental utility gained from the newly developed product all have a possible effect developers’ contributions to the common good. The study concludes by discussing some of its limitations and directions for future research.
ACKNOWLEDGEMENTS

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Molly Wasko and Eric von Hippel are sincerely thanked for sharing their thoughts and vision on online knowledge sharing and collaborative user-innovation. Also I could not have done without the support of Luke Segars and Tamás Nepusz and, last but not least, Massimo Garbuio and Don Scott-Kemmis, for encouraging me to dive deeper into to realm of open source than I ever dared to do on my own.

Daniel
SUMMARY

Balancing on the very nexus of open source development and traditional, proprietary innovation, the hybrid model of innovation combines the effectiveness of the former with the risk mitigating benefits of the latter (Ulhøi, 2004, Table 1). In strong contrast to the very principles of the open source movement the model allows firms to keep certain cards close to their chest, as carefully crafted license models permit commercial parties to cleverly combine open and closed block of software code. And though not in line with the original commandments of open source (Raymond, 1999), it is this very characteristic that convinced an ever increasing number of software firms to embrace the model.

The present study is particularly interested in whether software developers, knowing perfectly well commercial parties are right there to capitalise on the large number of contributions made by ever so many voluntary user-innovators, will still be willing to keep up the peer-to-peer assistance mechanism that proved the prime building block of open source development. The report thus departs from the following research questions:

What motives lie at the root of software developers’ rationale for providing peer-to-peer assistance in ‘gated’ open source projects?

Employing social network analysis of the Stackoverflow.com community, archival data of the website at hand and, finally, a survey among a random sample of its members, the research contributes to the status quo by 1) introducing a new model of software developers’ motives for contributing to hybrid innovation efforts, and 2) establishing whether significant differences exist between developers’ rationale for joining ‘full’ and gated open source projects. Proceeds of this effort are expected to benefit both scholars who intend to study the hybrid innovation paradigm in more detail, and practitioners aiming to outsource their innovation process themselves.

Hypotheses

Departing from an interpretation of the hybrid innovation model in which its actors are confined to 1) the innovation orchestrator who, either with or without strategic partners, aims to boost the development of new technologies; 2) the orchestrator’s pre-selected strategic or supply chain partners, and 3) cooperating user-innovators who consider conjoint software development the most efficient way to meet their unique needs and wants, this research assumes user-innovators to be motivated by 1) economic incentives: the financial rewards proceeding from participating in the development community, and the incremental utility a developer gains from the newly developed solution to his need or want; 2) individual incentives: a developer’s expertise, tenure in the field, the enjoyment he
gets from helping out peers, his sense of efficacy, kinship with the open source ideology, and finally the intellectual challenge of solving complex problems; and 3) social incentives: embeddedness in the community, commitment towards that community, anticipated reciprocity, and finally the pursuit of a higher reputation.

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Table 1 Theoretical fit of the hybrid model of innovation

Methodology

Aiming to map the presumed effect of individual, economic and social motives on developers’ knowledge contribution, the research employed a non-experimental, relational design.

First, a random sample of members of the Stack Overflow support forum were asked to fill in an online questionnaire. Secondly, social network analysis was applied to determine participants’ embeddedness in the Stack Overflow community. Third, public XML data were downloaded from the Stack Overflow public data dump to assess peer assigned helpfulness scores, as well as tenure in the field at hand. PLS analysis was finally employed to interpret the proceeds of this course of action.

607 people were approached to fill in the questionnaire, of whom a total of 244 respondents completed the survey — yielding an overall response rate of 42.1%.

Nine of the twelve indicator variables included in the study were quantified through survey research. All measures for doing so were derived from earlier, peer-reviewed publications. Embeddedness was measured by calculating individual developers’ degree of betweenness centrality (Freeman, 1979). Data for quantifying expertise and tenure were all
derived directly from the Stack Overflow public data dump, while knowledge contributions—
the study’s dependent variable—were finally quantified by determining the latent factor at
the root of both the number and actual helpfulness of individual postings.

All data were imported in SPSS for exploratory analysis. Subsequently SmartPLS was
employed to conduct confirmatory Partial Least Squares analysis—a structural equation
modeling technique that simultaneously assesses the reliability and validity of the
measures of theoretical constructs, and estimates the relationships among these constructs
(Wold, 1982).

The proposed model was characterised by a fairly good fit. All but the self-efficacy and
tenure measures had good construct reliability, while doubts concerning said factors were
taken away by their adequate ICR scores. Convergent reliability was warranted as all AVE
scores proved well above the .50 cut off point and, moreover, higher than the squared
corresponding cross-loadings. The fact that none of the individual items showed high
loadings on factors other than their own suggests proper discriminant validity as well.

Structural model fit was reasonable as well: 22.9% of the variance in knowledge
contribution was explained. Five out of twelve suggested links proved significant: tenure,
utility, commitment, ideology and embeddedness all had significant effect on the dependent
variable. No support could finally be found for the presumed effect of enjoy helping, self-
efficacy, ideology, intellectual challenge, financial rewards, reciprocity and commitment.

To determine whether significant differences exist in developers’ motivation for peer-
to-peer support in full and gated open source communities, the present findings were
compared to those gathered by Hertel et al (2003) and Wasko & Faraj (2005). Due to a lack
of available data, differences in the importance of expertise, tenure, self-efficacy and
embeddedness could not be assessed this way. The respective impact of the latter four was,
however, inspected by comparing actual effect sizes found by Wasko & Faraj (2005) and

Independent samples T-tests rendered enjoy helping ($t(798) = 6.3333, p < .001$), utility
($t(339) = 3.5304, p < .001$) and reputation ($t(339) = 3.6941, p < .001$) significantly different
under full and gated open source conditions.

The study concludes by presenting three different explanations for the high importance
of self-centred motives. First, online self determination has shown to become ever more
important in the online realm(Dellarocas, Fan, & Wood, 2004). Secondly, the widespread
availability of APIs and SDKs has rendered software development less of an intellectual
challenge—paving the way for a new generation of developers, attracted by a different set
of motives than their predecessors. Third, innovation communities led by commercial
parties have also been shown to attract a different breed of developers than do
communities who operate independently (Hars & Ou, 2002; Lakhani & Wolf, 2005).
Enjoyment in helping, the incremental utility gained from using the newly
developed product and, finally, the incremental reputation gained from involvement in the
development process finally all proved to differ significantly under full and gated open
source conditions. These findings are explained as follows. First of all, ever so often there is
significant overlap in what companies consider vital IP and what developers consider the
most challenging problems. Hedging such source material will automatically prioritise less
challenging development problems, and thus attract less skilled developers—who in turn
cannot cope without increased support of more experienced developers who like to offer a
hand once every now and then. Secondly, several major brands possess a coolness-factor
most people are gladly associated with. People who are more susceptible to such symbolic
value may very well also attach more value to their status among their peers. Third, the
early days of open source development were characterised by developers being attracted by
its ideology and the intellectual challenge of bottom up software development. As today the
widespread availability of APIs and SDKs has made software development a considerably
more accessible affair it seems only logical that in the absence of ample intellectual stimuli
people do expect increased utility from their efforts.

The study was limited in a number of ways. First, all data were plagued by a certain
degree of response bias, rendering all conclusions drawn from the research primarily
applicable to the most active participants. Secondly, the fact that the research deviates from
the usual intrinsic-extrinsic motivations continuum for online collaboration makes it
harder to make appropriate direct comparisons with other studies. Third of all, the present
study paid particular attention to the open source commandment to give, receive and
reciprocate. Though this peer-to-peer assistance mechanism has been shown to be the
prime building block of the open source development model (Lakhani & Von Hippel, 2003),
this does not mean that one’s motives for offering peer-to-peer support are the same as for
sharing new ideas or designs. Findings should, in thus, be interpreted with caution.

Finally the study suggests future research should look into the applicability of Nonaka’s
(1994) knowledge sharing framework in the context of hybrid innovation, as — if
applicable — doing to may yield valuable insights for firms that aim to tap into gated open
source communities themselves.
1. **INTRODUCTION**

Offering ubiquitous internet access, storage space for over two weeks of non-stop music playback and a user interface that, contrary to the status quo, did not require an MIT degree to comprehend, the Apple iPhone truly revolutionised the mobile industry. Throwing off immobilised industry giant as Nokia and BlackBerry, the iPhone’s considerable sales records provided then CEO Steve Jobs with enough confidence to claim the device was a sheer five years ahead of the competition.

If only he knew. Four years after its initial introduction Apple itself needs to pull out all the stops in order to keep up with a company that until very recently had shown not even the slightest of interest in developing a mobile phone. A company that was also known, however, for its remarkably close ties with the open source development movement, and a company that had proven to be able to turn entrenched industries upside down before.

Google.

Hand in hand with the development of the Android operating system, Google has perfected an innovation model we have now come to know as “hybrid” innovation (Harhoff & Mayrhofer, 2007; Shah, 2006). Balancing on the very nexus of open source development and traditional, proprietary innovation, hybrid innovation combines the effectiveness of the former with the risk mitigating benefits of the latter. In strong contrast to the very principles of the open source movement, the model allows firms to keep certain cards close to their chest, as carefully crafted license models permit commercial parties to cleverly combine open and closed block of software code. And though not in line with the original commandments of open source (Raymond, 1999), it is this very characteristic that convinced an ever increasing number of software firms to embrace the model.

Above paradox does seem to touch a raw nerve though. If anything, the success of open source development seems highly dependent on the “mundane but necessary” peer-to-peer assistance that individual developers provide in their ongoing search for intellectual incentives, and that, as a direct consequence of Linus’ Law¹, is generally considered to be at the root of the model’s renowned effectiveness and innovativeness (Lakhani & Von Hippel, 2003). In their ever pursuit of shareholder wealth maximization, firms however have no choice but to shield off key intellectual property at some point—begging the question whether developers, when their intellectual leeway is continuously sacrificed for the sake of profitability, will still find ample incentive to contribute, and the ongoing

¹ Widely accepted as officious open source movement mantra, Linus’ Law prescribes that as a development
commercialisation of open source communities thus proves a mere unintended killing of the goose that lay the golden eggs.

Aiming to shed new light on this matter, the present study draws on Organismic Integration Theory (Deci & Ryan, 1985): a sub-theory of Self-Determination Theory that dictates how extrinsic drivers and even personality traits\(^2\) can provoke *intrinsically* endorsed behaviour as well. In doing so, the study departs from the following question:

*What motives lie at the root of software developers’ rationale for providing peer-to-peer assistance in ‘gated’ open source projects?*

Drawing upon social network analysis of the Stackoverflow.com community, archival data of the website at hand and, finally, a survey among a random sample of its members, the research contributes to the status quo by 1) introducing a new model of software developers’ motives for contributing to hybrid innovation efforts, and 2) establishing whether significant differences exist between developers’ rationale for joining ‘full’ and gated open source projects. Proceeds of this effort are expected to benefit both scholars who intend to study the hybrid innovation paradigm in more detail, and practitioners aiming to outsource their innovation process themselves.

The remainder of this study then reads as follows. Section 2 presents an overview of the present literature on full and gated open source development; motivations for collaborative development in general, and earlier models that attempt to explain voluntary knowledge contributions in collaborative development efforts. Drawing on this considerable body of literature, Section 3 presents both a new model for collaborative user-innovation and a set of hypotheses on the relation between said motives and their respective effect on the volume and quality of one’s online knowledge contributions. Section 4 outlines the methodology employed to verify the validity of the hypotheses at hand, while Section 5 discusses the results of the present study. Section 6 presents a number of conclusions that can be drawn from the findings the study yielded, after which Section 7 concludes by discussing the limitations of the research as well as a number of possible directions for future research.

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\(^2\) Proposing a motivation-continuum that discerns between regulation, introjection, identification and finally integration, Deci & Ryan (1985) argue how extrinsic forces as norms and social constructs can be assimilated as an intrinsic incentive when the norm at hand is in line with the personality, norms and values of the individual. Coined “internalisation”, the process was originally defined as the active attempt of transforming extrinsic motives into personally endorsed values and thus assimilating behavioural regulations that were originally external (Ibid.).
2. LITERATURE REVIEW

Following up on a considerable number of 1990s essays on free and open source software development, psychologists, economists and finally management scientists all showed particular interest in the open source development model. The present section employs a systematic yet narrative review process in order to synthesise their findings on the various motives that are considered to drive collaborative user-innovation.

Publications were sought for by exploring the ABI/Inform, Emerald, IEEE Xplore, Google Scholar, Science Direct and Wiley InterScience databases, and by applying the snowball technique from there on. The search was limited to peer-reviewed journals and was based on the following keywords: motivations and motives for knowledge sharing, open source development and open source innovation, networks and communities of practice, collaborative and distributed innovation and finally collective action. Article abstracts were reviewed in order to eliminate those that were not actually related to the topic. Publications with an impact factor below 2.0 were finally excluded as well, as were articles that dealt with internal co-creation or the redistribution of ‘old’ knowledge.

2.1 On full and gated open source development

Traditional innovation strategies build on three key assumptions. One: consumers are the final link in the value chain. Two: users can choose between competing products, but have little say over their design or the way they are created. And three: firms will only innovate if they stand to make a profit from the new offerings they create. The stronger the intellectual property protection, the greater the incentive to innovate and therefore the higher the firm’s rate of innovation (Leadbeater, 2006).

Open source development breaks with all three of these conventions. Best understood as the antithesis of the linear development model, open source innovation incites innovators to a priori waive the rights to “critical knowledge components” in exchange for an entire army of bug identifying, code testing and co-developing engineers (Ulhøi, 2004). Formally defined as a development method “that harnesses the power of distributed peer review and transparency of process” (Open Source Initiative, 2011), informally Silicon Valley icon Bill Joy put it more strikingly when he stated that there simply “always will be more smart people outside your company than within”.

During the past decade proprietary and open source innovation strategies have grown remarkably close though. The fact that 1) user-innovators have come to tolerate commercial parties capitalising on their efforts while 2) an increasing number of firms now seem to appreciate the idiosyncratic characteristics of collaborative product development, heralded

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1 As derived from the ISI Web of Knowledge website
a development paradigm we now know as the **hybrid** model of innovation. Reaping the benefits of both the risk mitigating practices that linear innovation prescribes, and the wisdom of the crowds that lies in the communities open source projects are known for, the Google Android ecosystem probably manifests itself as the key exemplar of this shift.


A first conceptual model of firm-community collaboration is presented by Von Hippel and Von Krogh (2006), who discuss the private-collective model of innovation incentives. Drawing on the *private investment model*, which states that innovators appropriate financial returns from innovations through intellectual property rights, and the *collective-action innovation model*, which explains the creation of public goods, the private-collective model of innovation explains the development of public innovation through private funding. The theory prescribes that as long as the process-related rewards exceed the process-related costs, innovators are expected to profit more than the free riders consuming the public good, as they also benefit from the sheer process of creating that good.

Emulated by many, the private-collective model of innovation proved a particular stepping stone for Harhoff & Mayrhofer (2007) and Ulhoi (2004). Defining hybrid innovation practises as “stable arrangements, in which part of the innovation function is relegated to the user community, but the commercial oriented firm is capable of systematically and repeatedly appropriating monetary returns from the community generated innovations,” Harhoff & Mayrhofer tout the model as vehicle for enhancing customer loyalty, while Ulhoi considers hybrid innovation “the offspring of two fundamentally different, coexisting agency models, enabling the entrepreneur to combine and integrate various elements from each archetypal model”. Reckoning with the terminology used throughout the remainder of the present study, an adaptation of Ulhoi’s work is depicted in Table 2.4

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4 Ulhoi (2004) 1) uses a slightly different terminology and 2) does not take in account the different remuneration mechanisms employed in the open- and closed source innovation model.
2.2 What drives collaborative development?

Prior to the emergence of open source flagships as the Linux operating system and the Apache HTTP server, the general consensus read that any requirement for developers to release their efforts to the public domain would inevitably lead to the destruction of all incentive to innovate (Dam, 1995; Granstrand, 2000). Once, however, scholars began to understand how open source communities truly function, entrenched ideas on the necessity of intellectual property protection regimes, proved no longer adequate (Krogh & Von Hippel, 2006). The present chapter 1) synthesises the vast body of literature on currently known motivates for individuals to contribute to collaborative innovation efforts, and 2) discusses two earlier models that aim to shed light on the conditions under which user-innovators are willing to share their technology, knowledge and ideas with the outside world.

Though scholars have been studying collective action for decades (Olson, 1965), early publications were more concerned with the economic consequences than the psychological incentives at the root of the phenomenon (Arrow, 1962). Interest for the latter pivoted, however, after the publication of Stallman’s pioneering GNU Manifesto (1984), which presented an extensive argument against then emerging software license agreements that prohibited adjusting or redistributing earlier obtained software products. Stallman called upon developers to join him in his quest for “free” computer software by appealing to their sense of ideology and the intellectual challenge that he found inherent in collaborative

Table 2 Theoretical fit of the hybrid model of innovation

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Though it should be noted ‘free’, in this context, corresponds to ‘free speech’ rather than ‘free beer’ (Stallman, 1984).
innovation, and soon the MIT graduate had gathered a small army of co-operative software developers (Multinational Monitor, 2004).

Ideologically too Stallman found his allies. From the early 1990s to the turn of the millennium, scholars and opinion leaders published numerous essays that all appealed against the inefficiency and the, in their view, sheer unfairness of proprietary software development. The most influential one originated to Eric S. Raymond, whose Cathedral and the Bazaar (1999) manifesto eventually proved the final push in Netscape’s decision to release the source code to their Navigator web browser. Taking a less high-handed stance than earlier authors, the former sociologist also proved a pragmatic advocate of the open source process rather than its agenda, and while Stallman always assumed adherence to the “hacker” culture to underpin developers’ rationale for joining collaborative innovation projects, Raymond explains their contribution as commitment towards a specific community rather than a widely supported ideal.

The Cathedral and the Bazaar proved the kick off for a vast body of literature on collaborative software development in general and the various motivations that incite developers to join such projects in specific. A rigorous search for literature yielded 74 peer-reviewed publications that discuss a total of twelve different motives for contributing to collaborative innovation projects (Table 3). These motives were included in the present study when they were earlier adopted by at least one other peer-reviewed publication and, if such was the case, employed as a classifier in the chronologic overview of the retrieved literature outlined in Table 4 (Appendix C).

2.3 Earlier models

Though various models that weigh the different motivations for collaborative user-innovation exist (cf. Sharma, 2000; Krishnamurthy, 2006, and Subramanyam, 2008), two stand out in terms of theoretical scope and statistical fit.

A first effort originates to Roberts et al. (2006), who, drawing upon an extensive study of the Apache development community, discern between intrinsic motives as ideology, status- and opportunity motives as reputation, and internalised extrinsic motives as the “use-value” in the actual implementation of the product under development. Furthermore the authors’ model accounts for participation, education, performance and past performance — measures all derived from the Apache developers forums, and extrinsic motives that are measured by the average number of hours per week a developer spends on working on the Apache project and is actually paid for (Figure 1).
(Anticipated) reciprocity

The phenomenon that a person is motivated to contribute valuable information to his peers in the expectation that one will receive useful help and information in return (Kollock, 1999).

Commitment

A duty or obligation to engage in future action that arises from frequent interaction (Coleman, 1990).

Reputation

The social evaluation of the group of entities toward a person, a group of people or an organization on a certain criterion (Ghose, Panagiotis, & Sundararajan, 2009).

Enjoy helping

The intrinsic reward people may feel when helping their peers reach a commonly shared goal (Kollock, 1999).

Ideology

Adherence to specific norms, beliefs and values that may incite people to contribute knowledge or information to their peers (Stewart & Gosain, 2006a).

Self-efficacy

The belief a person’s action have an actual, profound effect on that person’s environment (Bandura, 1995).

Embeddedness

A person’s structural position in a network of peers (Wasko & Faraj, 2005).

Financial compensation

Any form of direct or indirect financial incentive to induce particular behaviour (Krishnamurthy, 2006).

Intellectual challenge

The fun, challenge and learning opportunities associated with helping and working together with peers (Wasko et al., 2009).

Utility

A measure of the extent to which the newly developed product fulfills a developer’s initial need to “scratch a personal itch” (Raymond, 1999).

Career perspective

The possibility for software developers to signal their talent towards potential employers (Lerner & Tirole, 2002).

Table 3 Definitions employed to establish whether given variables were included in earlier research

---

Figure 1 Motivations for online knowledge contribution, derived from Roberts et al. (2006).
Roberts et al. find that, in the context of the tightly governed Apache project, extrinsic motivations are positively related to developers’ status motivations but negatively related to their economic, use-value motivations. Intrinsic motives seem not affected by extrinsic ones: status motives actually enhance intrinsic motivation. Also extrinsic and status motives are found to increase developers’ contribution level (participation, in the above model), while use-value motivations lead to below-average performance. Intrinsic motivations then do not seem to impact developers’ contribution level, while the latter does positively affect developers’ eventual performance. Finally the authors find that past-performance rankings enhance developers’ subsequent status motivations.

Though successful in answering an earlier call for further clarification in the proliferation of motives and theories on collaborative innovation (Bogers, Afuah, & Bastian, 2010), Roberts et al.’s approach yields a somewhat coarse image of the different motives underpinning developers’ rationale to join collaborative innovation projects: arguably valid, the use-value, intrinsic and status and opportunity motives-continuum renders a less detailed image than richer variables as ideology, anticipated reciprocity and intellectual challenge do. Firms that aim to tap into the open source realm themselves may require a more detailed blueprint to get the most out of their renewed exploration of collaborative development, while for scholars, aiming to conduct further research on intrinsic and extrinsic motivation in online cooperation, a less liberal interpretation of the Self-Determination Theory probably entails a more grounded starting point.

To that extent, Wasko & Faraj (2005) are more successful. Building on an extensive study of an (unspecified) online knowledge sharing platform, the authors propose a model for information exchange that takes in account the effect of both intrinsic motives and that of “social capital”: the actual or virtual resources “that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalised relationships of mutual acquaintance and recognition” (Bourdieu & Wacquant, 1992)

The authors find people are particularly willing to contribute to the common good when they feel doing so will enhance their reputation, when feel they posses enough experience to contribute useful ideas and information, and when they are well embedded in the network at hand. Contrary to earlier findings, expected reciprocity or a high level of commitment towards the community were found to have no significant effect on people’s contribution level (Figure 2).

The downside of the Wasko & Faraj’s particular attention to intrinsic and social motives is the fact that extrinsic drivers as financial rewards, the economic utility of the product under development and, finally, the career benefits that may proceed from public knowledge exchange, all remain underexposed. Though the relative importance of such incentives may be less in the context of a community that is primarily concerned with knowledge management rather than new product development, Deci & Ryan (1985)
presented an extensive argument why extrinsic drivers, especially when in line with the norms and beliefs of the individual at hand, make for strong intrinsic incentives as well—and should not be left out of the equation².

In conclusion, while the model by Roberts et al. yields valuable insight in the interrelationships between the various intrinsic and extrinsic motives that underpin developers’ rationale for joining collaborative innovation projects, the fact that the authors’ model provides a coarse and undetailed image of the matter at hand decreases its suitability as starting point for further research as well as its applicability in practise. The model by Wasko & Faraj does lay significant emphasis on the social motives neglected by Roberts et al., but in turn pays for little attention to the extrinsic forces that were shown of particular importance by Deci & Ryan (1985).

Taking in account these shortcomings, the model presented in the next section draws on intrinsic, extrinsic and social motives to draw as clear an image of user-innovators’ rationale for contributing to online knowledge sharing platforms as possible.

Figure 2 Knowledge contribution model, derived from Wasko & Faraj (2005)
3. HYPOTHESES AND MODEL BUILDING

As the earlier model by Wasko & Faraj (2005, Section 2.3) fails to include important external motives as financial rewards and utility, and the model by Roberts et al. (2006, same section) assumes a bird’s eye perspective that neither allows for discerning between individual factors nor takes in account the importance of the very social motives shown of particular importance by aforementioned authors, the present study introduces a new model for user-innovation contributions in gated open source development that includes individual, economic and social motives.

Departing from an interpretation of the hybrid innovation model in which its actors are confined to 1) the innovation orchestrator who, either with or without strategic partners, aims to boost the development of new technologies; 2) the orchestrator’s pre-selected strategic or supply chain partners, and 3) cooperating user-innovators who consider conjoint software development the most efficient way to meet their unique needs and wants, this research assumes user-innovators to be motivated by 1) economic incentives, as the financial rewards that may proceed from commercialising the collaboratively developed product, the practical benefits of the product under development compared to its (proprietary) predecessor, and the opportunity for individual developers to demonstrate their programming skills to potential employers; 2) individual incentives, as the intellectual challenge that comes with every technological leap of progress, affinity with the open source ideology, and obtaining a sense of efficacy; and 3) social incentives, as one’s embeddedness in an innovation community, commitment towards that community, and anticipated reciprocity (Figure 3).

![Figure 3: User-innovation in the hybrid model of innovation](image-url)
3.1 Hypotheses

Building on an extensive literature review and, in particular, the work of Lerner & Tirole (2002), Krishnamurthy (2006) and Wasko & Faraj (2005), 12 factors are expected to affect user-innovators’ knowledge contributions to the software development platform (Figure 4).

![Hypotheses Diagram]

3.1.1 Individual motives

Expertise

Earlier research showed that individuals with higher levels of expertise feel more confident about the accuracy of their knowledge, and are therefore more likely to provide advice to peers (Constant, Sproull, & Kiesler, 1996). Later studies found that community members are less likely to contribute when they feel their expertise to be inadequate (Wasko & Faraj, 2000). People with a higher expertise on the topic at hand are thus
expected to make more frequent and more valuable contributions to the innovation community.

**H1** People with a higher expertise level will make more frequent and more valuable contributions to the development platform.

**Tenure**

In line with the above, Wasko & Faraj (2005) reason individuals with longer tenure in the field at hand have a better understanding of the relevance of their expertise—and are therefore better equipped to help out their peers. People with a longer track record in the innovation community are thus expected to be more valuable to the collective.

**H2** People with a higher tenure level will make more frequent and more valuable contributions to the development platform.

**Enjoyment in helping others**

Though better defined a personality trait than a direct motivator, Organismic Integration Theory (Deci & Ryan, 1985) suggests traits too can invoke intrinsic motivation when extrinsic forces as norms and social constructs are in line with the values and beliefs of the individual at hand (p. 18). Drawing on this premise, Wasko & Faraj (2005) find individuals are motivated intrinsically to contribute knowledge to others because engaging in intellectual pursuits, collaborative problem solving and simply helping peers can be challenging and fun. People who obtain more intrinsic rewards from doing so are, therefore, expected to contribute more frequent, higher quality answers to the problems of their peers.

**H3** People who enjoy helping others will make more frequent and more valuable contributions to the development platform.

**Self-efficacy**

Developers’ sense of efficacy has to do with their belief to “succeed” in a specific context or situation (Bandura, 1977). The concept lies at the centre of last-mentioned’s social cognitive theory, which emphasises the role of observational learning and social experience in the development of one’s personality (Ibid.). According to the author, people with high self-efficacy—that is, those who are convinced they can perform well—are more likely to view difficult tasks as something to be mastered, rather than something to be avoided. Again drawing on Organismic Integration Theory, highly efficacious people are expected to be more inclined to contribute to collaborative innovation than others.
H4 People with higher sense of efficacy will make more frequent and more valuable contributions to the development platform.

Ideology
The free and open source movement are, albeit to a varying extent, both characterised by a strong and widely shared ideology. Commitment to the ideal that one should be allowed to make adjustment to the source code of rightfully purchased software products, is long considered an important driver for participating in collaborative development (cf. Stallman, 1984). A prime example of internalisation, people who feel a stronger kinship with the open source ideology are therefore expected to make more frequent and higher quality contributions to collaborative innovation projects.

H5 People who feel a stronger kinship towards the open source movement in general, will make more frequent and more valuable contributions to the development platform.

Intellectual challenge
The intellectual challenge inherent in any technological leap makes for an important driver to join collaborative innovation efforts as well (Stallman, 1984). Similar to the above, people who are more receptive to the pursuit of intellectual fulfilment are more likely to contribute to online knowledge sharing platforms.

H6 People who are more receptive to the pursuit of intellectual fulfilment will make more frequent and more valuable contributions to the knowledge sharing platform.

3.1.2. Economic motives

Financial returns
The importance of financial benefits for individual developers in collaborative innovation projects has been subject to heated debate. Von Hippel (2001, 2006) states user-innovators typically only benefit from their own “internal use” of the innovation at issue, while Lakhani & Wolf (2005) too find 87 per cent of all developers never benefit financially from their efforts. Hars & Ou (2002), Andrews (2002), Butler et al. (2002) and notably Subramanyam & Xia (2008) suggest, however, otherwise: especially in hybrid innovation collectives as the Apache web server community, a higher status — resulting from long, high-quality contributions to the development forums — is linked to significant financial remuneration. Drawing upon these findings, higher financial remuneration is expected to positively affect developers’ contribution to the platform.
People who receive higher financial returns from participating in the development community will make more frequent and more valuable contributions to the development platform.

Utility
Virtually all open source innovation projects were brought in to life to “scratch a personal itch” (Raymond, 1999): PERL was created because earlier programming languages did not allow for reusing and re-combining programming ‘routines’, the Apache Software Foundation was established because the earlier NCSA server was too unstable, and the Firefox was started because the industry standard Internet Explorer web browser offered little functionality and was considered too unsafe (Hars & Ou, 2002; Kushner, 2006).

Discussing a number of striking milestones in thirty years of open source development, Hars & Ou (2002) find open source developers are often users of the product under development as well. Users’ and developers’ interests are, therefore, aligned too: both users and developers are interested in improving functionality, and both users and developers are willing to invest in those improvements. The non-financial utility of the product under development is, thus, expected to make for an important drivers as well.

People who gain the most non-financial utility from participating in the development community will make more frequent and more valuable contributions to the development platform.

3.1.3. Social motives

Reputation
Best defined as “the social evaluation of the group of entities toward a person, a group of people, or an organization on a certain criterion” (Ghose, Panagiotis, & Sundararajan, 2009), reputation was first rendered a measurable construct when eBay started to offer its members the possibility to rate their counterparty’s performance on a relatively simple 1 to 5 scale of stars (Roberts et al., 2006). According to the Self Determination Theory (Deci & Ryan, 1985) people will always strive to maximise and maintain their status amongst peers. As in the open source realm a person’s status is a direct derivative of his contribution to the product under development (Roberts et al., 2006), a higher reputation is expected to positively affect knowledge contributions to the community: the higher one’s status, the more that person will be inclined to maintain that appearance amongst his peers.

People with a higher reputation level will make more frequent and more valuable contributions to the development platform.
Commitment

Coleman (1990) defines commitment as the obligation to undertake future action on the basis of earlier interaction—either with an individual or a collective. Later research shows such a sense of obligation is an important motive for providing peers with advice (Constant et al., 1996) and to “pay back” the collective and the profession as a whole (Wasko & Faraj, 2000). Co-operating user-innovators who feel a stronger sense of commitment towards the community are, therefore, more likely to assist their peers than others.

H10 People who feel a stronger commitment towards the knowledge sharing platform at hand or open source development in general, will make more frequent and more valuable contributions to the development platform.

Reciprocity

The phenomenon of anticipated reciprocity stems from a sense of ‘mutual indebtedness’: in order to ensure on-going supportive exchanges, community members feel they must reciprocate the benefits they receive from others (Shumaker & Brownell, 1984). Wellman & Gulia (1999) find that, though online knowledge exchange occurs through weaker ties than is the case in ‘offline’ relationships, knowledge sharing in such networks is still facilitated by a strong sense of reciprocity and, also, a strong sense of fairness (Wellman & Gulia, 1999). People more receptive to this norm of reciprocity are expected to contribute more frequently; people less receptive are expected to contribute less.

H11 People who are more receptive to the norm of reciprocity will make more frequent and more valuable contributions to the development platform.

Embeddedness

The structural links between the various members of a social network have long been considered important predictors of collective action. Early research on the matter already demonstrated that individuals more centrally embedded in a community are more likely to have developed a high proportion of direct ties to other members and, thus, effective cooperation habits (Burt, 1992; Putnam, 1995).

Drawing upon this line of reasoning, people who obtained a more central “structural position” in the innovation community (Wasko & Faraj, 2005) are expected to make more frequent and higher quality contributions.

H12 People who have obtained a higher degree of centrality in the development community will make more frequent and more valuable contributions to the development platform.
4. METHODOLOGY

Aiming to map the presumed effect of individual, economic and social motives on developers’ knowledge contribution, the research employed a non-experimental, relational design. First, a random sample of members of the Stack Overflow support forum were asked to fill in an online questionnaire. Secondly, social network analysis was applied to determine participants’ embeddedness in the Stack Overflow community. Third, public XML data were downloaded from the Stack Overflow public data dump to assess peer assigned helpfulness scores, as well as tenure in the field at hand. PLS analysis was finally employed to interpret the proceeds of this course of action.

4.1.1. Sample

Within three years of its realisation Stack Overflow has become the prime knowledge sharing platform for computer programmers of all kinds and sorts. Today the platform still distinguishes itself from regular Q&A sites through fast and high quality peer-to-peer support—a feat found to arise from 1) a carefully crafted voting and reputation system to incite competition amongst member; 2) visible enactment of the site’s founders to incite credibility, and 3) a democratic voting system to continuously improve the site’s design to incite users’ commitment (Mamykina, Manoim, Mittal, Hripcsak, & Hartmann, 2011).

Stack Overflow features the ability for users to ask, answer and edit questions, and, through membership and active participation, vote those questions and answers up or down. Reputation points and ‘badges’ can be earned through valuable contributions. As of February 2012 the platform harbours over 1 million registered users who asked and answered over 2.6 million questions. All of the site’s content is licensed under a Creative Commons license, thus making it highly appropriate for scholarly research. Both static forum data as subscription date and peer assigned expertise-badges were derived by analysing the site’s public data dump, as were network data regarding members’ embeddedness in the network.

A first batch of 403 Stack Overflow members were randomly approached by email to fill in a questionnaire at obsurvey.com. With no less than 84 people filling in the questionnaire within the first three hours, the initial response rate can be considered high, but, as the response rate dropped significantly over the next days, a reminder was still send out three days later. Five days after the initial batch of participants were approached a new batch of 102 people were asked to fill in the questionnaire as well. They too received a three...
day reminder, after which a last batch of again 102 people were approached one week after the survey had launched. The questionnaire was then closed two days later, when the number of valid respondents was considered high enough for reliable structural equation modelling.

All together 607 people were approached to fill in the questionnaire, of whom 28 could not be reached due to an out of date or incorrect email address. Still a total of 244 people completed the survey—yielding an overall response rate of 42.1%.

Two remarks need be made though. First of all a mistake was made in the first mailing, in that the URL of the questionnaire ended in a question mark. As internet browsers tend to interpret all subsequent punctuation as part of the actual web address, the entire first batch of potential respondents were confronted with an error page. The fact that a relatively large number of people were still able to fill in the questionnaire can only be ascribed to the high technology standards of the sample.

Second of all the questionnaire was closed fairly quick after the third batch of people were approached: 200 participants were considered a large enough sample for reliable structural equation modelling (Iacobucci, 2010), while fitting in new survey data with the already acquired forum and social network analysis data proved a particularly painstaking and time consuming task. In addition to the above remark, the fact that several people sent in complaints about them no longer being able to fill in the questionnaire once it had closed, give reason to believe that, if necessary, the actual response rate may have been even higher than the current number.

To explore the possibility of non-response bias, Armstrong and Overton (1977) suggest late and non-respondents are often similar in their view on the topic at hand. An ANOVA test was conducted to compare knowledge contribution, reputation, embeddedness, tenure and expertise scores among early (the fastest 25%) and late (the slowest 25%) respondents. Though significant difference in the knowledge contribution scores for fast (M = 709313; SD = 2181537) and slow (M = 5023049; SD = 18581678) respondents were found (t(146) = 2.275, p = .024), all other tests proved not significant. The possibility for non-response bias was taken in account while analysing the study’s findings though.

In conclusion, two exclusion characteristics were employed. First, only those members who actually had participated in the development of gated open source projects were invited to fill in the questionnaire. Examples of the definition of such projects were given in the initial mailing; people who were still in doubt about whether they met the criteria to participate were invited to email the author (Appendix A).

Second, respondents who failed to fill in a (valid) user ID were excluded from the sample as well, as the user ID was employed as a necessary identifier to link survey responses to forum and network analysis data. Sample characteristics are finally presented in Table 4 to 8.
<table>
<thead>
<tr>
<th>Region</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>13</td>
<td>6.5%</td>
</tr>
<tr>
<td>Australia/New Zealand</td>
<td>3</td>
<td>1.5%</td>
</tr>
<tr>
<td>Europe</td>
<td>112</td>
<td>57.7%</td>
</tr>
<tr>
<td>North America</td>
<td>63</td>
<td>31.3%</td>
</tr>
<tr>
<td>South America</td>
<td>5</td>
<td>2.5%</td>
</tr>
<tr>
<td>-</td>
<td>5</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

*Table 4: Participants’ origin distribution*

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<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Male</td>
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<td>96.0%</td>
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<tr>
<td>Female</td>
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<td>1.5%</td>
</tr>
<tr>
<td>-</td>
<td>5</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

*Table 5: Participants’ gender distribution*

<table>
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<tr>
<th>Prime Profession</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithmic trader</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Designer</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Engineer</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Entrepreneur</td>
<td>3</td>
<td>1.5%</td>
</tr>
<tr>
<td>Functional analyst</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>IT Consultant</td>
<td>6</td>
<td>3.0%</td>
</tr>
<tr>
<td>Lecturer</td>
<td>2</td>
<td>1.0%</td>
</tr>
<tr>
<td>Manager</td>
<td>5</td>
<td>2.5%</td>
</tr>
<tr>
<td>Marketer</td>
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<td>0.5%</td>
</tr>
<tr>
<td>Medic</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Scholar</td>
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<td>5.6%</td>
</tr>
<tr>
<td>Software developer</td>
<td>145</td>
<td>73.6%</td>
</tr>
<tr>
<td>Statistician</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>Student</td>
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<td>8.1%</td>
</tr>
<tr>
<td>Unemployed</td>
<td>1</td>
<td>0.5%</td>
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<tr>
<td>Venture capitalist</td>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>-</td>
<td>6</td>
<td>3.0%</td>
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*Table 6: Participants’ prime profession distribution*
<table>
<thead>
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<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 20</td>
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<tr>
<td>20-30</td>
<td>95</td>
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<tr>
<td>30-40</td>
<td>64</td>
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<tr>
<td>40-50</td>
<td>20</td>
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<tr>
<td>Above 50</td>
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</tr>
<tr>
<td></td>
<td>7</td>
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Table 7: Participants age distribution

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-year college degree</td>
<td>23</td>
</tr>
<tr>
<td>4-year college degree</td>
<td>71</td>
</tr>
<tr>
<td>Doctorate-level degree</td>
<td>10</td>
</tr>
<tr>
<td>High school degree</td>
<td>27</td>
</tr>
<tr>
<td>Master-level degree</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

Table 8: Participants’ highest education distribution

4.1.2. Operationalisation and measurements

Nine of the twelve indicator variables included in the study were quantified through survey research. Measures for doing so were all derived from earlier work in the field: the scales measuring the self-efficacy, financial rewards and utility were adapted from Hars & Ou (2002); reputation, commitment and reciprocity were measured by means of scales developed by Wasko & Faraj (2005); the ideology scale was adapted from Lakhani & Wolf (2005), while the enjoyment in helping and intellectual challenge scales were finally taken from Wasko & Faraj (2009, Table 9). Actual items, presented on a 1-5 Likert scale, can be found in Appendix B.

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7 Wasko & Faraj (2005) study an online legal community which they refer to as “the Message Boards”. In line with the terminology employed throughout the remainder of this study, each reference to the Message Boards was changed to “the forum”.

8 The items in this survey were adopted in that “network of practice” was replaced by “the forum”.

35
Embeddedness was measured by calculating individual developers’ degree of betweenness centrality (Freeman, 1979). In online communities, a “dyadic link” is created between two individuals when one person responds to another’s posting. To determine individual centrality these links were recorded in a social network matrix: if a link existed a one was placed in that cell—if not a zero was filled in instead. This measure of centrality assesses to how many peers an individual is connected, independent of the total number of messages posted. A person who exchanges 40 messages with 25 unique peers has a high centrality (degree = 25), while a person who exchanges 40 messages with only one peer has a low centrality (degree = 1).

Mathematically, for any graph $G = (V,E)$ with $n$ vertices (V) and ditto edges (E), the betweenness $CB(v)$ is computed as follows:
1. For each pair of vertices $(s,t)$ all shortest paths between them are calculated.
2. For each pair of vertices $(s,t)$ the fraction of shortest paths that pass through the vertex in question (here, vertex $v$) is determined.
3. This fraction over all pairs of vertices $(s,t)$ is summed up (Equation 1).

$$CB(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

Equation 1 Betweenness centrality calculation (L.C. Freeman, 1979)

As existing software solutions proved not capable to cope with very large social networks as the Stack Overflow community, the iGraph implementation of the Brandes algorithm was employed to determine participants’ betweenness centrality (Csardi o-
Nepusz, 2006). As the measure yielded somewhat skewed data, a square root transformation was applied to ensure normality.

Data for quantifying expertise and tenure were all derived directly from the Stack Overflow public data dump. Expertise was measured by determining the number of ‘badges’ a participant received over the course of his Stack Overflow membership. Developers can award such badges to their peers when they consider an answer to demonstrate significant expertise in a given subject. As this measure yielded somewhat skewed data, a log transformation was applied to ensure normality.

Tenure was derived from the public data dump as well. The difference between the date of calculation and forum members’ subscription date yielded their tenure in the field.

Knowledge contributions were last of all quantified by determining the latent factor at the root of both the number and actual helpfulness of individual postings. An individual’s total number of postings can be determined in a similar manner as one’s tenure in the field: by using the readily available forum data. Stack Overflow also employ sophisticated voting mechanisms to determine the quality of a given answer. Building on this mechanism, the study takes in account a participant’s total number of answers (volume) as well as the difference between the up and down votes a participant received on those answers: the net helpfulness, so to say.

4.1.3. Analysis

All data were imported in SPSS for exploratory analysis. Subsequently SmartPLS was employed to conduct confirmatory Partial Least Squares analysis—a structural equation modeling technique that simultaneously assesses the reliability and validity of the measures of theoretical constructs, and estimates the relationships among these constructs (Wold, 1982).

The decision to apply this particular technique rests on two arguments. One: several indicator variables were derived from real world data, which increases the chance for multicollinear, non-normally distributed data. PLS analysis has long proven more robust to deviations from normality than classical structural equation modelling techniques do (Marcoulides, Chin, & Saunders, 2009).

Two: PLS is widely used in information system research in general and virtual collaboration in specific (cf. Ahuja et al., 2003; Chin & Todd, 1995; Wasko & Faraj 2005). As PLS analysis would thus allow for easier comparison of research findings, the choice for said technique was considered appropriate.
5. RESULTS

Apart from general items regarding participants’ origin, gender, profession, education and age, all questions included in the online questionnaire were mandatory. As expertise and tenure scores were derived directly from the Stack Overflow data dump, and embeddedness was calculated automatically as well, no data were missing.

Expertise, embeddedness and tenure scores were significantly skewed though. PLS analysis is known to be robust to violations of the normality assumptions, but asymptotic data may still affect path coefficients (Vinzi, Chin, & Henseler, 2009). A square root transformation was therefore applied to embeddedness, and a fifth root transformation to reputation. Apart from suffering from skewed data, the expertise measure also proved highly correlated to the knowledge contribution. For reliability sake the item was dropped from the eventual model.

Tenure proved highly skewed as well. A striking subsample of participants subscribed over 60 months before conducting the research, whereas other respondents averaged around 40 months. An independent samples T-test was conducted to compare knowledge contribution scores among participants above and below 60 months of tenure. As no significant difference in the scores for high (M = 6860401; SD = 25667856) and low (M = 2068285; SD = 11049154) tenure conditions were found (t(198) = 1.796, p = .074), and the data distribution was ragged rather than asymptotic, the variable was still included in the final model.

Visual assessment of histograms and Kolmogorov-Smirnov measures confirmed all indicator variables but tenure met the assumption of normality, while inspection of boxplot diagram showed there were no outliers among the data. Multicollinearity was assessed by inspecting VIF scores, which all proved well below the suggested cut-off value of 10 (Myers, 1990, Table 11). Bartlett’s test of Sphericity turned out significant ($\chi^2(351) = 2218.58$, $p < .0001$), while Kaiser’s measure of sampling adequacy was .705 — rendering the data appropriate for factor analysis. Specific survey results are finally presented in Appendix C.

5.1 MEASUREMENT MODEL

All scales employed in the research were derived from earlier, peer reviewed publications in the field, strengthening the author in his belief construct validity was warranted. Construct reliability was assessed by inspecting all items’ Cronbach’s alpha (Table 11). As both the self-efficacy and the utility measure fell below the suggested .70 — .80 interval for adequate reliability, construct reliability measures (ICR) were examined as well. All constructs scored well above the suggested cut-off point of .70 (Werts, Linn, & Jöreskog, 1974, Table 10) and were therefore included in the final model.
Convergent reliability was assessed by inspecting the Average Variance Extracted. Capturing the amount of variance in relation to the amount of variance caused by measurement error, Fornell & Larcker suggest AVE scores should exceed .50 in order to warrant validity (1981, Table 10). All constructs proved well above the cut off point and were thus kept in the final analysis.

<table>
<thead>
<tr>
<th>Mean</th>
<th>SD</th>
<th>Cronbach’s α</th>
<th>ICR</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Enjoy helping</td>
<td>4.45</td>
<td>.5167</td>
<td>.808352</td>
</tr>
<tr>
<td>2.</td>
<td>Commitment</td>
<td>4.01</td>
<td>.7332</td>
<td>.812563</td>
</tr>
<tr>
<td>3.</td>
<td>Financial rewards</td>
<td>2.22</td>
<td>.9011</td>
<td>.827343</td>
</tr>
<tr>
<td>4.</td>
<td>Ideology</td>
<td>3.24</td>
<td>.9498</td>
<td>.743504</td>
</tr>
<tr>
<td>5.</td>
<td>Intellectual challenge</td>
<td>4.34</td>
<td>.5738</td>
<td>.722120</td>
</tr>
<tr>
<td>6.</td>
<td>Reciprocity</td>
<td>3.75</td>
<td>.7992</td>
<td>.801059</td>
</tr>
<tr>
<td>7.</td>
<td>Self-efficacy</td>
<td>3.91</td>
<td>.5892</td>
<td>.641824</td>
</tr>
<tr>
<td>8.</td>
<td>Utility</td>
<td>3.58</td>
<td>.6244</td>
<td>.599541</td>
</tr>
<tr>
<td>9.</td>
<td>Tenure</td>
<td>46.89</td>
<td>11.0981</td>
<td>-</td>
</tr>
<tr>
<td>10.</td>
<td>Reputation</td>
<td>3.80</td>
<td>.6343</td>
<td>.692957</td>
</tr>
<tr>
<td>11.</td>
<td>Embeddedness</td>
<td>36.35</td>
<td>15.3838</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 10 Multi-item factor measures

Discriminant validity was assessed by determining whether the square root of AVE scores were higher than corresponding correlations (Fornell & Larcker, 1981, Table 11). As this proved to be the case for all constructs discriminant validity seemed not to be at stake.

<table>
<thead>
<tr>
<th>VIF</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
<th>10.</th>
<th>11.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Enjoy helping</td>
<td>1.093</td>
<td>.849</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Commitment</td>
<td>1.178</td>
<td>.354</td>
<td>.847</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Financial rewards</td>
<td>1.078</td>
<td>.033</td>
<td>-.044</td>
<td>.808</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Ideology</td>
<td>1.114</td>
<td>-.002</td>
<td>-.036</td>
<td>.182</td>
<td>.810</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Intellectual challenge</td>
<td>1.289</td>
<td>.304</td>
<td>.395</td>
<td>-.035</td>
<td>-.013</td>
<td>.796</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Reciprocity</td>
<td>1.897</td>
<td>.158</td>
<td>.356</td>
<td>.071</td>
<td>.115</td>
<td>.269</td>
<td>.909</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Self-efficacy</td>
<td>1.181</td>
<td>-.276</td>
<td>.141</td>
<td>.121</td>
<td>.176</td>
<td>.011</td>
<td>.219</td>
<td>.850</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Utility</td>
<td>1.138</td>
<td>.103</td>
<td>.000</td>
<td>.186</td>
<td>.497</td>
<td>-.100</td>
<td>.080</td>
<td>.259</td>
<td>.743</td>
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<tr>
<td>10.</td>
<td>Reputation</td>
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<td>-.139</td>
<td>.038</td>
<td>-.127</td>
<td>-.209</td>
<td>-.155</td>
<td>-.053</td>
<td>-.042</td>
<td>-.050</td>
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<tr>
<td>11.</td>
<td>Embeddedness</td>
<td>1.017</td>
<td>-.049</td>
<td>-.022</td>
<td>.053</td>
<td>.114</td>
<td>-.058</td>
<td>.035</td>
<td>.101</td>
<td>.007</td>
<td>-.056</td>
</tr>
</tbody>
</table>

Table 11 Correlations matrix. Diagonal elements (bold figures) are the square roots of the variance and their measures. Off-diagonal elements are the correlations among the constructs.

Chin (1995) advises to inspect individual factor and cross-loadings as well. Because of high cross-loadings, utility 1 and 2, self-efficacy 1 and reputation 3 were removed from the final model. As none of the remaining items in Table 12 show high cross-loadings, adequate discriminant and convergent validity seem warranted.
<table>
<thead>
<tr>
<th>Enjoy helping 1</th>
<th>Embeddedness 1</th>
<th>Commitment 1</th>
<th>Financial Rewards 1</th>
<th>Ideology 1</th>
<th>Intellectual Challenge 1</th>
<th>Reciprocity 1</th>
<th>Self-efficacy 1</th>
<th>Reputation 1</th>
<th>Tenure 1</th>
<th>Utility 1</th>
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<tbody>
<tr>
<td>.8091</td>
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<td>.1479</td>
<td>-.0138</td>
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<td>.1020</td>
<td>.0488</td>
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<td>.0581</td>
<td>.1059</td>
<td>.1178</td>
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<tr>
<td>Enjoy helping 2</td>
<td>.8820</td>
<td>-.0640</td>
<td>.5472</td>
<td>-.0228</td>
<td>-.0145</td>
<td>.2056</td>
<td>.1382</td>
<td>.2299</td>
<td>.0468</td>
<td>.0668</td>
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<tr>
<td>Enjoy helping 3</td>
<td>.8550</td>
<td>-.0134</td>
<td>.3764</td>
<td>-.0441</td>
<td>-.0035</td>
<td>.4741</td>
<td>.1987</td>
<td>.2449</td>
<td>.0933</td>
<td>.0873</td>
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<td>Embeddedness*</td>
<td>-.0469</td>
<td>1.0000</td>
<td>-.0221</td>
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<td>-.0575</td>
<td>.0357</td>
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<td>-.0992</td>
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<td>.2412</td>
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<td>.0644</td>
<td>.1017</td>
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<td>.0223</td>
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<td>-.0072</td>
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<td>.0342</td>
<td>.0664</td>
<td>.0824</td>
<td>.0210</td>
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<td>-.0881</td>
<td>.0499</td>
<td>.5666</td>
<td>.3378</td>
<td>.0927</td>
<td>.1435</td>
<td>.1437</td>
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<td>.0167</td>
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<td>.1360</td>
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<td>.2047</td>
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<td>-.0668</td>
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<td>-.0129</td>
<td>.8608</td>
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<td>-.0174</td>
<td>-.0092</td>
<td>-.0615</td>
</tr>
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<td>.8634</td>
<td>.1980</td>
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<td>.2370</td>
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<td>-.1465</td>
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<td>.1232</td>
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<td>.1270</td>
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<td>.1831</td>
<td>.0684</td>
<td>.0252</td>
<td>.2186</td>
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<td>.3145</td>
<td>.1355</td>
<td>.1112</td>
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<td>.2557</td>
<td>.4895</td>
<td>.3249</td>
</tr>
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<td>Tenure</td>
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<td>-.1290</td>
<td>-.0398</td>
<td>-.0105</td>
<td>-.2260</td>
<td>-.1811</td>
<td>-.0472</td>
<td>.5683</td>
<td>.1000</td>
</tr>
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<td>.0444</td>
<td>.1743</td>
<td>.1898</td>
<td>-.1029</td>
<td>.1367</td>
<td>.1933</td>
<td>.1209</td>
<td>.0190</td>
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<td>-.0287</td>
<td>.1265</td>
<td>.4529</td>
<td>-.0631</td>
<td>.0645</td>
<td>.1515</td>
<td>-.0975</td>
<td>-.0594</td>
</tr>
<tr>
<td>Utility 5</td>
<td>.1078</td>
<td>-.0335</td>
<td>-.0109</td>
<td>.1247</td>
<td>.4684</td>
<td>-.0647</td>
<td>.0862</td>
<td>.2247</td>
<td>-.1505</td>
<td>-.0382</td>
</tr>
</tbody>
</table>

**Table 12**: Factor analysis and constructs. For actual wording, see Appendix B. (* = Transformed (see Section 4.1.2.))
5.2 STRUCTURAL MODEL

The hypotheses presented in Section 4 were tested by applying the bootstrapping method (Chin et Todd, 1995, 200 sub-samples). Explaining 22.9% of the variance in developers’ knowledge contribution, the overall fit of the model in Figure 5 was in line with earlier findings by Wasko et Faraj (2005) and Chiu et al. (2006). As set apart in the previous section, hypothesis 1 could not be tested due to severely skewed and correlating data. Tenure, however, proved to have a highly significant effect on participants’ knowledge contributions (β = .159, p < .001), providing support for hypothesis 2 (Table 13). No significant links were found between respectively enjoy helping, self-efficacy, intellectual challenge, financial rewards and knowledge contribution, though ideology did prove to positively affect the dependent variable (β = .084, p < .1) — providing support for hypothesis 5.

A significant path was found between utility and developers’ knowledge contribution as well (β = .132, p < .05), providing support for hypothesis 8. In line with hypothesis 10 and 12, both commitment and embeddedness were found to have a significantly effect too (β = .123, p < .05;  β = .097, p < .05), whereas the presumed effect of reputation only approached significance (β = .159, n.s.). No support could finally be found for the effect of reciprocity on the dependent variable (β = .023, n.s.).

<table>
<thead>
<tr>
<th></th>
<th>Beta</th>
<th>T-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Expertise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Tenure</td>
<td>0.3393*</td>
<td>8.913127</td>
</tr>
<tr>
<td>3. Enjoy helping</td>
<td>0.0476</td>
<td>0.713571</td>
</tr>
<tr>
<td>4. Self-efficacy</td>
<td>-0.0494</td>
<td>0.849270</td>
</tr>
<tr>
<td>5. Ideology</td>
<td>0.0937*</td>
<td>1.235626</td>
</tr>
<tr>
<td>6. Intellectual challenge</td>
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<tr>
<td>7. Financial rewards</td>
<td>0.0883</td>
<td>0.619784</td>
</tr>
<tr>
<td>8. Utility</td>
<td>0.1317**</td>
<td>1.634781</td>
</tr>
<tr>
<td>9. Reputation</td>
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<td>0.896417</td>
</tr>
<tr>
<td>10. Commitment</td>
<td>0.1234***</td>
<td>2.632825</td>
</tr>
<tr>
<td>11. Reciprocity</td>
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<td>0.480253</td>
</tr>
<tr>
<td>12. Embeddedness</td>
<td>0.0966*</td>
<td>1.237098</td>
</tr>
</tbody>
</table>

Table 13 Effects on dependent variable. *** p < .001; ** p < .05; * p < .1
In conclusion, the proposed model was characterised by a fairly good fit. All but the self-efficacy and tenure measures had good construct reliability, while doubts concerning said factors were taken away by their adequate ICR scores. Convergent reliability was warranted as all AVE scores proved well above the .50 cut off point and, moreover, higher than the squared corresponding cross-loadings. The fact that none of the individual items showed high loadings on factors other than their own suggests proper discriminant validity as well.

Structural model fit was reasonable as well: 22.9% of the variance in knowledge contribution was explained. Five out of twelve suggested links proved meaningful and significant: tenure, commitment, embeddedness, ideology and utility all had a significant, positive effect on the dependent variable. No support could finally be found for the presumed effect of enjoyment in helping, self-efficacy, intellectual challenge, financial rewards, reputation and reciprocity.

**Figure 5** Structural model
5.3 POST-HOC TESTS

The present section concludes by discussing a comparison of the present findings with earlier findings in the context of development communities not affected by the involvement of a commercial party, and two alternative models only taking in account either knowledge contribution volume or quality.

5.3.1. Comparing motives for full and gated open source projects

To determine whether significant differences exist in developers’ motivation for peer-to-peer support in full and gated open source communities, the present findings were compared to those gathered by Hertel et al (2003) and Wasko & Faraj (2005). Both studies examine individuals’ knowledge contribution in the context of knowledge communities as well, but specifically do so in the context of a community not led or affected by a commercial party. All variables taken in account in Table 14 were derived in a similar manner as was the case in the present study; all studies included pay particular attention to the software industry, and no significant differences exist among the definitions employed to operationalise the variables included in the respective studies.

Five indicator variables could, however, not be assessed by utilising the method outlined above: financial rewards, expertise, tenure, self-efficacy and embeddedness. The respective impact of the latter four was, however, inspected by comparing actual effect sizes found by Wasko & Faraj (2005) and Chiu et al (2006), who employed the earlier authors’ model in the context of a Java support group. Financial rewards could not be included in this comparison as to the author’s best knowledge, no earlier, peer-reviewed study examined the effect of this particular variable on developers knowledge contributions levels.

Independent samples T-tests were employed to compare earlier results by Hertel et al (2003) and Wasko & Faraj (2005) with the present findings, rendering enjoy helping (t(798) = 6.3333, p < .001), utility (t(339) = 3.5304, p < .001) and reputation (t(339) = 3.6941, p < .001) significantly different under full and gated open source conditions. For further details see Table 14.

---

9 Wasko & Faraj (2005) do account for expertise, tenure and embeddedness as well, but determine the variables at hand in a different manner. One-on-one comparison is therefore not appropriate.
Table 15 Differences in motivation for full and gated open source participation. * p < .001.

Employing the method by Rosenthal & Rubin (1982) individual effect sizes of expertise, tenure, self-efficacy and embeddedness were compared (Table 16).

Table 16 Effect size comparison following Rosenthal (1982).

Following Rosenthal, the weighted mean \( \bar{d} \) is then given by:

\[
\bar{d} = \frac{\sum_{j=1}^{K} w_j d_j}{\sum_{j=1}^{K} w_j}
\]

Equation 2 Determination of \( \bar{d} \)

And the corresponding \( \chi^2 \)-value by:

\( ^{10} \) Rosenthal & Rubin (1982) introduce an extensive procedure for comparing the effect sizes of two or more independent studies. They include a method for calculating the approximate significance level for the heterogeneity of effect sizes of studies, and a method for calculating the approximate significance level of a contrast among the effect sizes—which, according to the authors, proves a reasonable alternative for comparing findings among various studies when raw data are not available.
\[ \chi^2 = \sum_{j=1}^{k} w_j (d_j - \bar{d}) \]

**Equation 2** Determination of corresponding χ²-values

Employing above methodology, neither expertise (χ² = .72, df = 1, p = n.s.), tenure (χ² = .0018, df = 1, p = n.s.), self-efficacy (χ² = .43, df = 1, p = n.s.) nor embeddedness (χ² = 1.26, df = 1, p = n.s.) proved to differ in effect size under full and gated open source conditions.

### 5.3.2. Alternative models

In order to determine the effect of the various variables introduced in Section 3 on either developers’ contribution volume or quality, the present section concludes by discussing two models that predict only the body or the respective helpfulness of participants’ input. The implications of these findings are discussed in the next section.

Explaining 17.6% of the variance in developers’ input volume, the model depicted in Figure 6 renders tenure in the field (β = .260, p < .001), kinship with the open source ideology (β = .088, p < .1), incremental utility (β = .109, p < .1) and finally embeddedness in the development community (β = .122, p < .01) significant predictors of the dependent variable. Contrary to the model discussed in the previous section, commitment to the forum at hand proves no longer significant (β = .070, n.s.), while reputation finally only approached the threshold value (β = .175, n.s., Table 17).

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**Table 17** Effects on contribution volume. *** p < .001; ** p < .05; * p < .1
As far as contribution quality is concerned, the model in Figure 7 renders commitment to the development forum ($\beta = .159, p < .01$), tenure in the field ($\beta = .365, p < .001$), and finally incremental utility ($\beta = .109, p < .1$) significant predictors of developers’ contribution helpfulness. While at .237 the model’s $R^2$ is actually slightly higher than is the case in the original model in the previous section, no significant path between embeddedness in the community and kinship with the open source ideology could be found. Further data are provided in Table 18.
**Figure 7** Structural model confined to contribution helpfulness

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**Table 18** Effects on contribution helpfulness. *** p < .001; ** p < .05; * p < .1
6. CONCLUSION AND DISCUSSION

Over the past three decades scholars have published an impressive body of literature on the matter what moved so many user-innovators to join collaborative innovation platforms. As research on the matter accumulated, so did an ever increasing number of possible explanations (cf. Hars & Ou, 2002; Hertel, Niedner, & Herrmann, 2003; Lakhani & Von Hippel, 2003). Not for nothing various scholars called for a more straightforward, unifying explanation of the topic at hand (cf. Bogers et al., 2010).

The present study provided a partial answer to this call. Weighing nearly all motives suggested to underpin developers’ rationale for contributing to such projects, a new model was introduced that explains how each and every one of these motives affects developers' contribution quality and volume. Developers’ tenure, social embeddedness and commitment to the community proved of particular importance, as did kinship with the open source ideology and the incremental utility gained from the newly developed software product. Status among peers and the financial gains proceeding from contributing to the jointly developed end-product only approached significance, while enjoyment in helping out peers, the intellectual challenge that comes with doing so and, finally, anticipated reciprocity all proved not significant— rendering user contribution to hybrid innovation efforts a seemingly self-centred affair: while early advocates of the collaborative innovation paradigm as Raymond (1999) and Stallman (1984) suggested altruism and ideals to be the main forces behind the model’s success, modern hybrid innovation platforms appear to centre on self-determination (Deci & Ryan, 1985). Before moving to a one-on-one comparison of motives for joining full and gated open source projects, a number of possible explanations for this chasm are discussed.

Over the past ten years, communication means have changed. In the early days of open source development developers employed private mailing lists and IRC11 channels for determining which way to go next. Today, most communication happens out in the open, on blogs, internet forums and social networks. Rather than the secure environment of mailing lists and private chat channels, modern open source projects are of a much more exhibitionist nature: contributions can be seen not only by a small number of peers, but by most of the outside world as well.

Early open source platforms functioned primarily as an assembly point for human capital. Modern, hybrid open source platforms offer large stocks of social capital as well: development communities no longer function as mere virtual assembly halls, but have become self-advertisement platforms (Dellarocas et al., 2004), job agencies (Lerner & Tirole, 2002) and tech-minded Facebook alternatives (Mamykina et al., 2011). As far as the present

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11 Internet Relay Chat
findings are concerned, the relative importance of tenure, commitment, and embeddedness in gated communities prove anything but an exception to that tendency.

The high importance of utility is best explained by the fact that today, the online realm looks significantly different from what it looked like around the turn of the millennium. Ten years ago Google had yet to go public, Internet Explorer was the default web browsers, and very few companies offered APIs to tap into. Building a software application was a cumbersome affair and only true fanatics had a role to play in bottom up, open source development.

Nowadays, adapting software to your own needs is easier than ever. Each operating system comes with APIs and SDKs to meet your every need, and each website on computer programming will tell you step-by-step how to get things going if you want to adjust or modify software you just bought or downloaded for free. As the barrier for getting involved with software development was lowered considerably, people’s rationale for doing collectively so may have changed as well (Cockburn, 2006). If anything, the present findings render the personal itch—suggested ever so important by Raymond (1999)—still quite an important incentive.

Interestingly, the present study also showed kinship with the open source ideology to be a force to be reckoned with in hybrid innovation platforms. As discussed in Section 5.3.1, firms’ increased involvement with software development communities seems to attract a different breed of developers: ‘gated’ developers assign more value to reputation, expect higher increased utility and, surprisingly, also appear to be more willing to help out peers in need. Support for the notion that hybrid innovation communities leave no room for the very ideals open source development built on could, however, not be found—rendering suggestions made in the introduction of this report in fact mute. Implications of these findings are discussed in more detail, however, in Section 6.2.

Apart from the above, this study was also interested in in whether companies’ interference with software development communities would affect developers’ motivation to provide peer-to-peer support. Enjoyment in helping, the incremental utility gained from the using the newly developed product and, finally, the incremental reputation gained from involvement in the development process all proved to differ significantly under full and gated open source conditions.

The fact that enjoyment in helping peers becomes a more important motive for involvement in open source development communities is best explained by the trend that companies, once involved in such communities, are often quick to shield off key intellectual property. Ever so often there is significant overlap in what companies consider

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12 Application Programming Interfaces
13 Software Development Kits
vital IP and what developers consider the most challenging problems, thus forcing community members to seek intellectual satisfaction in, for instance, educating their peers.

As far as the increase in the importance of reputation is concerned, a possible explanation is provided by the fact several major brands possess a coolness-factor most people are gladly associated with. People who are more susceptible to such symbolic value may very well also attach more value to their status among their peers. Rindova et al. (2006), for instance, hinted in this direction.

The increased importance of utility is finally probably not so much something to be ascribed to firms’ newfound interference with open source platforms, but to people’s reasons for joining development communities in the first place. As set apart above, in the early days of open source development developers were attracted by its ideology and the intellectual challenge of bottom up software development. As today the widespread availability of APIs and SDKs has made software development a considerably more accessible affair, it seems only logical that in the absence of ample intellectual stimuli people expect increased utility from their efforts. Whereas full open source development has been long considered analogue to kinship with a liberated, anarchic ideology, gated open source development thus proves primarily an effective means for maximising one’s very own utility curve.

6.1 Limitations of the present study

As discussed in Section 3, open source development draws on three main pillars: 1) a resource model that builds on peer leadership, an obligation to give, receive, and reciprocate, and the notion that good ideas come from scratching a personal itch; 2) a development model that builds on modularised code, quick and frequent release cycles, and extensive involvement of the development community, and 3) the open source ideology that code should be open, distributed through ‘copyleft’ system and protected through a ‘copyright’ one (Lakhani & Von Hippel, 2003). The present study paid particular attention to the first-mentioned obligation to give, receive and reciprocate. Though this peer-to-peer assistance mechanism has been shown to be the prime building block of the open source development model (Ibid.), this does not mean that one’s motives for offering peer-to-peer support are the same as for sharing new ideas or designs. To that extent, hybrid innovation involvement may still be an altruistic and idealistic matter.

Secondly, the present data were plagued by a certain degree of response bias. As participants’ time to respond seemed strongly related to their reputation at Stack Overflow, conclusions drawn on the basis of the present findings primarily hold for the most active
breed of open source contributors. Future research should be cautious when drawing generalisations from the present findings.

A third limitation stems from the theoretical lens this research departed from. The deliberate choice for a knowledge based perspective is in perfect line with the axiom that the online realm is, in essence, an economy based on knowledge barter (Smith & Kollock, 1999). Earlier efforts to explain collaborative innovation usually built on the resource based view of the firm. This approach yielded highly valuable insights as well—not least the open innovation paradigm (Chesbrough, 2003)—but the resource based view of the firm remains a pragmatic and materialistic one, and therefore hard to reconcile with some of the less discrete factors unmistakably at the root of user-innovators’ choice for collaborative innovation. The study’s adaptation of the capital-based nomenclature introduced by Wasko & Faraj (2005) seems, to that extent, a fair compromise.

Fourth, the research deviates from the usual intrinsic-extrinsic motivations continuum for online collaboration. Deci & Ryan (1971) already made a case for internalised extrinsic motives, and also Wasko & Faraj’s plea for social capital and Roberts et al.’s particular attention to use-value and status- and opportunity motives suggests the intrinsic-extrinsic motivation taxonomy echoes a perspective on things that is just too simplistic to truly uphold reality (Wasko & Faraj, 2005; Roberts et al., 2006). Though supported in its decision to abandon the intrinsic-extrinsic motivation framework by, among others, Deci & Ryan (1971), the study’s decision to do so does make it more difficult to draw a one-on-one comparison between the findings empirical analysis of the model presented in this synthesis would yield, and the earlier findings from open source research from the early 2000s (cf. Hars & Ou, 2002).

Fifth and finally, this research built on three types of data. One: subjective survey data for measuring reciprocity, commitment, reputation, enjoyment in helping others, kinship with the open source ideology, one’s sense of efficacy, susceptibility to financial rewards, susceptibility to intellectual challenges, and finally the incremental utility gained from using the newly developed product. Two: objective data derived directly from the Stack Overflow public data dump, used to determine developers’ expertise, tenure in the field, contribution volume and contribution quality. And three: computer-generated data to determine developers’ social embeddedness in the Stack Overflow community.

As PLS has been shown robust to deviations form normality, survey data could be included in the model employed in the present study without significant pains. Once transformed to counter the asymptotic nature of the data, computer-generated embeddedness data could be included readily as well. Data derived directly from Stack Overflow proved, however, troublesome. Expertise data in particular proved not only highly skewed and ragged—the data proved also correlated to the dependent variable to such an extent, the variable had to be dropped from the eventual model. As irrespective of their nature none of the variables seemed to have a significantly different effect on the study’s dependent variable, to over-correlate with said variable or, moreover, to affect other
measures in any possible way, the deliberate choice for including data of varying nature seemed justified.

6.2 Scholarly and managerial implications

For firms, becoming involved in open source development appears an attractive option. The prospect of intellectual stimuli and increased utility proved ample incentive for a rapidly increasing workforce of creative, efficient and highly skilled employees, who not only seem at rest with firms’ ever increasing involvement with innovation networks, but also actually seem to prefer being associated with ‘cool’ companies.

Three items appear of vital importance for any company aiming to tap into the open source realm though. First, findings supporting the high importance of tenure, commitment and embeddedness rendered developers’ urge for social development a key factor in building a successful community. To that extent, proprietary forums that are only accessible to a small subsample of developers no longer suffice: firms aiming to leverage the full potential of open source development should acknowledge the social edge of collaborative development and allow for public development, tap into existing solutions as Stack Overflow and Github, and make sure they stay as true to the open source ideology as possible.

Secondly, the lowered barrier for effective software development resulted in a decreased number of developers joining open source efforts for the inherent intellectual challenge, but also in an increased number of developers who joined for the ability to encourage and help starting software developers. Firms aiming to start a successful community should therefore allow for ample peer-to-peer support opportunities — again by tapping into, for instances, Stack Overflow-like platforms.

Last of all, though developers have little difficulty with firms’ increased involvement in the open source realm, they do expect increased utility in return. Firms cannot hedge all key source code, as doing so would limit developers in their quest for better software. The decision what source material to shield off and what bits and pieces to release should therefore not be made on intellectual property related grounds alone: as noted earlier by Ulhoi (2004), too few crumbs to play with will eventually kill all incentive to innovate.

Apart from above issues, firms’ should also have a clear understanding of what they aim to obtain from their open source efforts. Companies in search of a lean, high quality stock of contributions should best maximise social capital: developers who participate in the community over a longer period of time and develop significant commitment towards that community, are more likely to provide high quality support to the common good. Such is
best achieved by leveraging existing platforms, as for instance Google, Microsoft and Adobe have long shown to work fairly well (Mamykina et al., 2011).

Companies in search of a large, vivid community should, however, best strive to maximise their developers perception of embeddedness, act in accordance with the open source ideology, release ample source code to provide intellectual stimuli and attainable utility gains, and employ some kind of reputation system so developers can build a reputation. In contrast to the lean, high quality contribution platform outlined above, developers attracted to participate in such communities are best incentivised by staying true to the nature of open source development. Generous source code releases allow for accessible increased utility, while peer-leadership and developer involvement in the community’s management should warrant participants’ perception of the open nature of the community. Firms should, however, carefully weigh the balance in code to be released to win the hearts and minds of the community, and code to be kept proprietary to warrant shareholder wealth maximisation: the internet has long shown to be a place where secrets don’t last.

From a scientific point of view, this research finally departed from the Organismic Integration Theory: Deci & Ryan’s (1985) suggestion that even utterly extrinsic forces as norms and social constructs can be assimilated as an intrinsic incentive when the norm at hand is in line with the personality, values and beliefs of the individual. Unfortunately, none of extrinsic variables included in the present study proved to have a significant effect on developers’ knowledge contribution, thus leaving the question whether the Organismic Integration Theory is applicable in the online realm too, still an open one.

6.3 Directions for future research

The study concludes by discussing some directions for future research. Set apart in Section 3, hybrid innovation is, in essence, the interplay of innovation orchestrators, their partners, and cooperating user-innovators. Though the present study sheds valuable light on the different drivers that motivate user-innovators to participate in such development networks, little is known about the actual knowledge sharing processes at play at the heart of such networks. Nonaka (1994) discerns four distinct types of organisational knowledge sharing:

1) **Socialisation**, which refers to the exchange of tacit to tacit knowledge. An example of this would be a football trainer demonstrating his pupils how to take a free kick.

2) **Externalisation**: the process of making tacit knowledge explicit. For example, shooting a video of a free kick demonstration session.
3) Combination involves merging explicit knowledge with other explicit knowledge. In the example, this would be using the previous video with other material in order to develop a better understanding of football as a whole.

4) Internalisation is finally changing explicit knowledge back into tacit knowledge by the practical implementation of doing what was specified in the explicit form. This would involve pupils scoring a free kick during an actual football match.

Research on the matter where and to what extent the knowledge sharing processes discerned by Nonaka actually take place in hybrid innovation networks may provide valuable insights for firms that aim to tap into gated open source communities themselves—thus providing an excellent starting point for future research (Figure 8).

Figure 8 Projection of Nonaka’s (1994) knowledge creation framework on the hybrid innovation model presented in Section 4 of the present study.
7. REFERENCES


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Wesley Publishing Company.


8. APPENDICES

8.1 Appendix A: original mailing

Hi firstname!

First of all, let me introduce myself. I am Daniel Visser, a postgrad business student from the Eindhoven University of Technology. I am currently working on my master thesis on the various drivers that I expect to underpin software developers’ motivation for participating in gated* open source projects as the Android operating system and the Apache web server.

I am particularly interested in the link between collaborative innovation and developers’ tendency to help each other out on forums as Stackoverflow.com—which is how I got a track of you personally. I found your email address either through extensive Googling, your Github account, or by copy-pasting it from your Stackoverflow profile page.

If you ever contributed to any open source project a commercial party built upon to make a profit—either through sales or support services—or built upon open source technology to develop your own app or software package, could you please help me out by filling in my survey? You’ll find it at 
Research has shown this to take only 3.48 minutes on average, though it should be noted that N=1 :) .

If you have any questions regarding my research or this particular questionnaire, don’t hesitate to send me a quick reply.

Thanks in advance!

Best regards,

Daniel

* To avoid any confusion, gated open source development has to with any kind of open source development in which a commercial party manages or affects the development community, shields off key intellectual property, and builds on the efforts of the community to warrant a certain profit margin.
8.2 Appendix B: item wording

All items below were to be answered through a 1 (strongly disagree) to 5 (strongly agree) Likert scale.

Enjoy helping 1  I like helping other people
Enjoy helping 2  It feels good to help others solve their problems
Enjoy helping 3  I enjoy helping others on the forum

Intellectual 1  Participating in the forum gives me the opportunity to learn new things
Intellectual 2  I participate in the forum to be exposed to complex problems and issues
Intellectual 3  I find participating in the forum interesting

Ideology 1  I believe that source code should be open
Ideology 2  I feel a personal obligation to contribute to open source software
Ideology 3  I dislike proprietary software and desire a different development model

Self-efficacy 2  Participating in the project gives me a feeling of competence
Self-efficacy 3  Participating in the project gives me a feeling of effectiveness

Commitment 1  I would feel a loss if the forum was no longer available
Commitment 2  I really care about the fate of the forum
Commitment 3  I feel a great deal of loyalty to the forum

Reciprocity 1  I know that other members will help me, so it’s only fair to help other members
Reciprocity 2  I trust that someone would help me if I were in a similar situation

Financial rewards 1  I am paid to work for the project
Financial rewards 2  I receive some form of explicit compensation (e.g., salary, contract) for participating in the project
Financial rewards 3  For me, working for the project is extremely profitable/not profitable at all
Financial rewards 4  Comparing to other programming jobs, working for the project is very well paid/very poorly paid

Utility 3  My participation in the open source project ensures that the software provides functionality that matches my unique and specific needs
Utility 4  It is hard for commercial software to meet my ever changing needs
Utility 5  Being able to fix problems with the software myself is one of the great advantages of open source software
8.3 Appendix C: research on motivation for open source development

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Table 4 Synthesis of the present literature. Publications that were cited more than once in another, peer-reviewed publication, are printed in bold. Qualitative studies are then denoted by an open circle; quantitative ones by a closed one, and publications that employ a mathematical exploration of the matter are denoted by a dotted circle.
8.4 Appendix D: survey results

Responses per day

Legend

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<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly agree</th>
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Enjoy helping 1  I like helping other people in general

Enjoy helping 2  It feels good to help others solve their problems
Enjoy helping 3  
I enjoy helping others on the forum

Intellectual 1
Participating in the forum gives me the opportunity to learn new things

Intellectual 2
I participate in the forum to be exposed to complex problems and issues

Intellectual 3
I find participating in the forum interesting
Ideology 1  
I believe that source code should be open

Ideology 2  
I Feel a personal obligation to contribute to open source software

Ideology 3  
I dislike proprietary software and desire a different development model

Self-efficacy 1  
Participating in the project gives me a feeling of accomplishment
Self-efficacy 2  Participating in the project gives me a feeling of competence

Self-efficacy 3  Participating in the project gives me a feeling of effectiveness

Commitment 1  I would feel a loss if the forum was no longer available

Commitment 2  I really care about the fate of the forum
Commitment 3  I feel a great deal of loyalty to the forum

Reciprocity 1  i know that other members will help me, so it’s only fair to help other members

Reciprocity 2  I trust that someone would help me if I were in a similar situation

Financial rewards 1  I am paid to work for the project
**Financial rewards 2** I receive some form of explicit compensation (e.g., salary, contract) for participating in the project

- Yes: 94%
- No: 57%
- Maybe: 36%
- Can't Say: 10%

**Financial rewards 3** For me, working for the project is extremely profitable/not profitable at all

- Yes: 84%
- No: 62%
- Maybe: 24%
- Can't Say: 4%

**Financial rewards 4** Comparing to other programming jobs, working for the project is very well paid/very poorly paid)

- Yes: 62%
- No: 115%
- Maybe: 43%
- Can't Say: 10%

**Utility 3** My participation in the open source project ensures that the software provides functionality that matches my unique and specific needs

- Yes: 95%
- No: 72%
- Maybe: 27%
- Can't Say: 10%
Utility 4  It is hard for commercial software to meet my ever changing needs

Utility 5  Being able to fix problems with the software myself is one of the great advantages of open source software