Attitude, involvement and participation in business open source software projects: an empirical analysis of developers' behaviours

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Abstract*—Referring to the Theory of Planned Behaviour and Social Cognitive Theory the objective of this article is to evaluate the influence of developer motivational factors on his/her participation level in open source business projects through his/her attitude and implication. Then we assess perceived resulting satisfaction gained from participation both on individual performance and project achievement. Literature analysis puts forward components of individual behaviour, intrinsic and extrinsic motivational factors, and performance variables of open source projects. Empirical analysis corresponds to a survey carried out on 310 participants in open source business projects hosted on the SourceForge web site. Compared to prior empirical research carried out on more popular open source software projects, our PLS analysis reveals some dissonant results. In particular, participatory behaviour is mainly associated with the motivation of reciprocity expected from peers while individual motivation such as learning expectancy, reputation gains, or ideology does not play a significant role. In the same vein, our results question the significant role of developer participation level on project completion and individual performance gains. Indeed the satisfaction level of the whole project team is observed as having a more significant influence on both performance variables.*

Keywords*—open source, motivation, behaviour, attitude, implication, participation, reciprocity, team satisfaction.*

I. Introduction

OSS represents today a new business market assimilated to a new source of business application outsourcing [1]. Recent research has seen the emergence of more professional business practices and open source communities can no longer be considered as a large group of freelance developers dedicated to the programming of proprietary challenging software development [2]. More and more projects are sponsored by corporations and participant financial retributions are current practice [3] However, this "new OSS generation", remains marginal up to now. Indeed, 60% of developers receive no financial retribution for participating in the development of open source projects [1] and most of them are aborted or abandoned before the beta version software has been distributed because of a lack of implication of participants [4]. As a whole, project teams are affected by high turnover [5] and the ratio between active and non active projects is considered as equivalent to the Pareto Law [6]. So the analysis of motivational factors, the participation and satisfaction of non-paid developers still remains a research objective to be scrutinized.

Existing literature offers a large spectrum of extrinsic and intrinsic motivational factors explaining why developers freely participate in software development: contributing to open source ideology [4], having fun coding software developed for personal usage [7],[8], improving technical competence, [9], enhancing their reputation toward peers [10],[11] and acquiring job opportunities [12] However, there is no consensus of the marginal influence of identified motivational factors on developer participation and project satisfaction level. In fact, recent empirical research has revealed motivational factors as belonging to a pattern resembling overlapping roof tiles or scales in which some of them can be mutually reinforced or opposed [13]. So the participation of open source developers ought to be considered as a complex mechanism by which assessing presupposed direct influence of motivational factors on participation level turns out to be inconsistent.

Referring to the Theory of Planned Behaviour [14], [15] and Social Cognitive Theory [16], we may consider participation as being preceded by indivisible emotional and psychological antecedents. The objective of this article is to evaluate the influence of developer motivational factors on his/her participation level in open source business projects through his/her *attitude* and *implication.* Then we assess the perceived resulting satisfaction gained from participation both on individual performance and project achievement. Literature analysis puts forward components of individual behaviour, intrinsic and extrinsic motivational factors, and performance variables of open source projects. Empirical analysis corresponds to a survey carried out on 310 participants in open source business projects hosted on the SourceForge web site. Compared to prior empirical research carried out on more popular open source software projects, our PLS analysis reveals some dissonant results. In particular, participatory behaviour is mainly associated with the motivation of reciprocity expected from peers while individual motivation such as learning expectancy, reputation, or ideology does not play a significant role. In the same vein, our results question the significant role of developer participation level in project completion and individual performance gains. Indeed the satisfaction level of the whole project team is observed as having a more significant influence on both performance variables. The discussion section develops the managerial and scientific implications of these results and the article concludes with future research investigation which could be carried out concerning open source governance in order to explore how open source project initiators could manage the OSS project team as a whole.

II. Literature analysis

Well-known open source applications such as the Linux operating system, the Apache Web Server or many others which are widely used, including user applications (e.g., Mozilla, Open Office) and programming languages (e.g., Perl, Python)—may give the impression that the majority of OSS projects succeed in retaining developers. However, the reality is different as large numbers of them are abandoned [17],[18] because they fail to attract and retain the developers' dedication [4]. Depending on developer behaviour, the outcome of a project can be vary dramatically.

A. Developer behaviour

In information system research, well known IT adoption theoretical models such as TAM [19], TAM2 [20] or UTAUT [21], conceptualized user behaviour according to the *Theory of Reasoned Action*, *Theory of Planned Behaviour* [14],[15] or *Social Cognitive Theory [22].* Behaviour corresponds to a resulting manner of acting, the outcome a person adopts in function to his/her own assimilation of different several psychological feelings shaping the way he/she participates [23].

Subjective norm is defined as *"the person's perception that most people who are important to him think he should or should not perform the behaviour in question"*. [24]. *Perceived behavioural control* corresponds to the *"perceived ease or difficulty of performing the behaviour" [14]* and can be assimilated to the *self efficacy* concept defined in

Social Cognitive Theory as the judgement of ones' ability to accomplish a specific task. This implies that behaviour is influenced mainly by social and individual dimensions. Both dimensions exist as a background to the research carried out with regard to the motivation factors of open source developers. However, most of them assessed their direct influence on participation level and neglected, in doing so, the intermediate effect of psychological antecedents such as *attitude* and *involvement.*

Attitude corresponds to positive or negative feelings to a stimulus [24]. It influences the intention to perform a task and ultimately the way the person behaves or is expected to behave [25]. In an open source project, developer *attitude* can correspond to his/her overall feeling about the announced software to be developed (its objective, functionalities, targeted users and so on). *Involvement* is defined *"as a subjective psychological state, reflecting the importance and personal relevance of an object or event"* [26]. In other words whereas *attitude* is an affective or evaluative judgement of a person with regard to an object or an event [24],[27], *involvement* corresponds to the importance level he/she acknowledges in acting or re-acting in an appropriate way to this stimulus. In the case of open source, developers can feel themselves more or less implicated in the project because of its scope, the competency required, their own availability and so on. *Participation* corresponds to the "visible part of the iceberg"and is defined as "taking part" or "contributing" to something [28]. In open source software, members' participation refers to the set of activities developers perform during successive stages of a project. These activities can be linked to specific phases of systems development such as feasibility analysis, software design, programming, testing and bug fixing, documenting and so on. OSS development is not designed in a "top-down" manner and users may contribute to this process as the source code is open to modification, enabling them to become developers and participate in expanding the code and fixing bugs. While we are aware that the participation of developers in open source projects is more an evolving construct than a static behaviour set, our focus in this particular research is to study the linkage between developer behaviour and its outcome at one particular point in time. We hypothesize further that developers with high levels of *attitude* and *involvement* present high levels of *participation*.

Even if isolating the aforementioned variables would not be consistent because of potential reductionist consequences, we can establish some distinctions between them. While *attitude* and *implication* refer to psychological states of mind or person as regards an external stimulus, *participation* corresponds to his/her actual behavior. In an open source project, effective achievements of software development largely depend on this last behavioural variable. For the requirements of our research, we distinguish *participation* from *attitude* and we consider *implication* as a twofold psychological antecedent reflecting the imbrication of overall feeling about the project's motivational factors. This distinction is all the more interesting in that psychological research has shown the way a person acts is not always consistent with his/her premonitions [29],[30]. A great deal of research in open source [31],[32],[18] has found that during the process of software development several changes in participation occurred as users shifted from passive to active users and from active users to developers without any obvious reasons. In other words, participation level in an open source project turns out to be the visible result of a complex mechanism on which motivational factors can only have an indirect influence on psychological antecedents as a whole. As a consequence, we have moved away from empirical investigations which tried to evaluate the direct marginal influence of motivational factors on participation level. Our investigation is better in line with other empirical research which has taken into account the mediating role played by *attitude* or *implication* in the e-commerce [33], buying process [34-36], decision process [37-39], work motivation [40] or health behaviour [41]. Concerning existing open source literature, Bagozzi and Uptal [42] adopted a similar reasoning in order to analyse Linux user behaviour ; our research can be considered as an extension to open source developers.

H1: Developers' *attitude* and *implication* towards OSS projects positively influences their *participation* level.

B. *Developer motivational factors*

Open source communities are considered as hybrid forms between private and collective models [5] putting into question traditional economic theories according to which agent behaviours and decisions are based on cost reduction and profit maximisation. Understanding motivational factors of an "invisible workforce" freely spending time and effort to develop business software invites us to identify individual and social dimensions associated with the way they behave. The following literature analysis is based on sociological and psychological theories as prior research on open source.

Psychological literature about individual motivations traditionally draws a distinction between *intrinsic* and *extrinsic* factors [43],[44]. A person is intrinsically motivated when he/she does not expect any retribution apart from the pleasure of carrying out the activity by itself [44]. Intrinsic motivations are often considered as primitive motives [45] and aim to satisfy human needs in terms of autonomy and competence acquisition. At the same time, individual behaviour is also shaped by extrinsic motivations which refer to rewards and sanctions likely to be used. Financial retribution incitations (we decided to leave this aside as one of our research objectives) or fears to be hierarchically blamed are evident examples of extrinsic motivations.

Existing literature on open source often articulates developer motivational factors with the *intrinsic-extrinsic* dialectic. However, it should be more considered as a continuum than a dichotomy [13]. Indeed, an extrinsic motivation can be *internalised [46]* when appropriated by a person who develops his/her self-regulating system. In open source communities, the ego-enhancement and professional opportunities quest can be cited as most illustrative examples [47]. While keeping in mind this continuum notion, our article aggregates both dimensions by distinguishing, on the one hand, *learning motivation, reciprocity expectancy* and *ideology* (intrinsic motivations) and, on the other hand, *professional opportunities* and *reputation enhancement toward peers* (internalized extrinsic motivations).

Individual motivation in social groups (such as those of which open source communities are part of) has been one of the hottest research topics in psychology and education science [48-50]. The *Goal oriented* concept issuing from these theories is acquiring a dominant approach in individual motivation research [51]. It implies making the distinction between expected learning goals and performance objectives aimed at by a person in terms of ability to achieve specific tasks. In existing literature, learning goals are among the most cited motivational factors for open source participants [52],[53],[9],[54],[18],[4]. Indeed, for a developer, an open source project can represent a suitable context to knowledge and expertise sharing, to discovering technical crafts and programming practice rules (for instance: the way scripts should be structured, the naming of objects and how they are used and so on). These knowledge acquisitions correspond to *learning by doing* in the sense of Brown & Duguid [55] who considered learning as a process embedded in action. In design science research in information systems, learning through this act of building appears like a consensus [56]. Lakhani *et al. [57]* observed that compared to private sector software, open source communities allow a higher feeling of creativity for participants. Existing literature illustrates this feeling with several notions such as enjoying coding, fixing bugs or technical problems associated with already used or about to be used software [5],[13].

H2: Expected learnings positively influence developer attitude and involvement in OSS projects.

Another developer intrinsic motivation is related to the identity conveyed by the open source community itself [47]. This feeling of social identity corresponds to a person's affiliation to a social group: *"social identity is the individual's knowledge that he belongs to a certain social group together with some emotional or value significance to him of this group membership" [58]*. From this definition two elements can be highlighted: (1) the extent to which a person considers himself as belonging to a group, and (2) the feeling of pride in belonging to this group. The latter is related to a self-enhancement motive and both should be considered more as interrelated parts of a virtuous circle more than straightforward antecedents of identity feelings. In a community, the social identity of participants tends to promote cooperation and reversely, cooperation tends to reinforce social identity [59].

Formerly, open source phenomena were raised with the objective of emancipating software development from the "commercial dictates" of private editors rarely allowing users to check if applications had been effectively programmed. The open source community conveys rich ideological considerations [60] and related identity feeling constitutes a federating vector of developer involvement and participation in spite of classical hierarchical central authority and commercial challenges [11]. Ideology is considered as cultural environment forming individual attitudes [61] The adherence to and sharing of some norms, values and beliefs of open source [4] shapes developer participation in OSS projects they are party to. *Norms* refer to behavioural expectations (norm as opposed to removing someone's name from a project without that person's consent, against splitting a project into numerous others, against using an inappropriate channel to distribute code and so on). *Values* refer to preferences for some behaviours or outcomes over others (the duty of developers to share information and help others, improving capabilities by exploring code in detail instead of settling for learning the minimum necessary). *Beliefs* are the basic assumptions referring to the underlying philosophy of the community (for instance the quality of the code produced is higher when the code is open and freely available than when it is privately developed for commercial purposes; bugs are more rapidly fixed when other people can intervene than when they are performed by fixed teams). This last concept corresponds to an ideological sector likely to shape individual contribution to OSS development and comprises the sector we are interested in. Based on this, we may hypothesize that:

H3: Open source beliefs positively influence developer attitude and involvement in OSS projects.

Literature about self-determined motivations considers

OS developer behaviour as also shaped by another social incentive: the expectancy of reciprocity. Reciprocation is defined as an individual contribution to a community with the expectancy that other participants will respond similarly [62]. The Game Theory shows that whenever the pay-off of a player is questioned by a rival's choice, the cooperation durability is jeopardized [63]. Reciprocation appears as a necessary condition to maintain cooperation stability and trust over time in organizations [64]. Contrary to the game theory meaning, reciprocity in the OS community differs from a win-win deal in one-to-one relationships. The concept is related to a more collective dimension which could be summarized as follows: "behave with the community members as I did with you". In this sense, reciprocity could be assimilated to altruism which is acting with no counterpart expectancy except the desire to maintain some social links [65]. However, electronic network-based communities sharply contrast with traditional ones where day-to-day social life is characterized by face-to-face exchanges enforcing expectation of reciprocity through social sanctions [66]. The social capital of a community is not likely to be fully recovered when transferred to an electronic practice network [67]. For instance, in electronic networks, participants have no control over other participants' responses on the forum and no assurance that the persons they are helping will not act like "free-riders". Moreover, electronic practice networks, such as open source communities, would simply disappear if too much free-rider behaviour occurred [66]. This reinforces the relevance of a satisfactory reciprocity shaping developer behaviour in OSS projects.

H4: Reciprocity motivation positively influences developer attitude and involvement in OSS projects.

Beyond intrinsic motivation, the *social exchange theory* [68] explained that actors engaged in social relations also hope for other retributions such as recognition by peers. Recognition builds up the reputation of a person defined as esteem, largely shared by the group he/she belongs to, of his/her nature and value [69]. Reputation supports the emergence of trust and represents the dissuasion power of people associated to their relations [70]. Building his/her reputation means gaining respect from other open source community members [7], [71] and implies being able to fix bugs, to be creative in coding [72] and to share knowledge and competency. This motivation is all the more important in that contrary to commercial software market, providing the source code they have developed free is an appropriate way for developers to render their work totally visible to community members and the public as well [47]. Also, developer reputation building is another way to capture the attention of the environment and eventually to seek professional opportunities [52].

H5: Reputation motivation positively influences developer attitude and involvement in OSS projects.

Apart from the learning orientation, developer behaviour is also shaped by performance expectancy. Indeed, Dweck [73] notes that a person may operate in both systems of learning and performance goals. Venkatesh and others define performance expectancy in the context of information systems as the "degree to which an individual believes that using the system will help him or her to attain gains in job performance" [21]. It includes perceived usefulness, relative advantage, and outcome expectations. In the context of OSS development, participants may expect several outcomes from their contributions to OSSP. For instance, Hann *et al.* [12] observed that for 122 Apache project developers, potential career impacts from participation appeared as a strong motivational factor in OSS development. Other expectations put forward by preliminary research include enhancing the effectiveness of developers in their specific jobs. In this way, just like "freelance" developers, developers of OSS projects are likely to look for some professional experiences allowing them to improve their job effectiveness and to have career opportunities.

H6: Expected professional opportunities positively influence developer attitude and involvement in OSS projects.

C. *Performance outcomes*

As presented above, learning orientation shapes individual cognitive response patterns [74] and consequently the way this individual behaves in terms of *attitude*, *involvement* and *participation* towards the work he performs. Learning orientation has been suggested in order to change how day-to-day work is achieved, knowledge is used and competence developed. Recent findings from empirical analysis in OSS projects revealed that both knowledge transfer and knowledge creation were possible because of the re-experience enabled by displaying source code and *transactive group memory* [75]. The authors consider that the on-line functionalities of host forges tend to compensate for the absence of face-to-face contact. For instance, commentaries added in code programs and CVS systems allow developers to review the process that lies behind code developed by others. Being able to review the whole history of code development allows developers to be engaged in reflective observation and to learn from improvements and errors previously made. To distinguish individual performance levels, we based our empirical analysis on results provided by Hogg & Terry [76] and Kankanhalli [77] that establish three levels in knowledge creation and transfer processes. The first, *replication*, refers to mastering techniques and methods necessary to carry out daily tasks. The second, *adaptation*, concerns the ability of a person to actualise his knowledge in order to adapt his resolution mode to environmental changes. Finally, *innovation*, corresponds to the attitude of a person who transforms his cognitive schemes and creates new resolution modes representing a significant added value in problem solving.

H7: Developer participation positively influences individual performance.

A developer can also be more or less satisfied with the outcome of the project itself with regard to the contribution he devoted to it. Taking into account this dimension is of critical importance as several OSS projects are abandoned before their closure [4] or are associated with results which do not match initial assigned objectives [11]. Indeed, a lot of OSS projects evolve in such a way that finally developed software serves other needs than those of the project initiator [13].

H8: Developer participation positively influences project performance.

III. Research design

Beyond literature analysis and aforementioned hypotheses, this section presents moderating variables we took into account with regard to our research objective, the research model and the survey apparatus applied to the SourceForge.org platform in order to test it.

A. Moderating variables

Recent research in IS development observed poor project impetus as one of main factors of project failures [78]. As suggested in the literature review, developer satisfaction of intrinsic and extrinsic motivations is supposed, all things being equal, dependent on his effective participation in an OSS project. By doing this, we consider it is because of his contributions made publicly available that his motivations in terms of learning, reputation gains, professional opportunities and so on could be satisfied. In this quest, depending on its innovative objectives, an open source project can represent a more or less appropriate vector of developer motivation satisfaction. For instance, developing a user friendly Content Management System such as "concrete5"[1] represents, *a priori,* a more attractive project than others consisting of coding a straightforward patch for an existing office application. A certain prestige can be attributed to an OSS project depending on its innovative objective which we put forward to be considered as a moderating variable of the influence of motivational factors on *attitude* and *involvement.*

H9: Innovative objective of the OSS project positively influences developer *attitude* and *involvement.*

Some authors [79],[80] have considered that a high level of virtual work in teams can be unproductive to innovating task achievement because of limits of electronic communication channels to tacit knowledge transfer. Recently, Hanisch & Corbitt [81] observed that global software development poses many challenges (especially during requirements engineering phase) when team members are located in widely distributed geographic locations. These conclusions, in line with richness media theory assumptions, are not consistent with Tsoukas [82] who considered tacit knowledge as not having to be captured and translated into explicit knowledge, but likely to induce new knowledge when distilled through social relations. Literature in Management Science with regard to cooperation is abundant in what concerns team dynamics. If a team is often considered as the basic unit of organisational learning, [83] some empirical researches [84-86] have observed that knowledge transfer quality between people was a function of their proximity in terms of demographics, socio-cultural and professional status links. The open source phenomenon represents a specific context because of its open social network of individuals scattered across the world and who theoretically do not meet or know each other. According to the game theory, we might be sceptical about the optimal effectiveness of a social network whose members are likely to develop opportunistic behaviour. However, the ideology shared in the open source community and corresponding cooperation norms [87] incite us to be apart from these considerations. In their empirical research on open electronic networks, Mc Lure Wasko & Faraj [66] observed that individuals participated and made their expertise available to others when they considered it might enhance their reputation, but also because they were attracted by the dynamism of the team. In the same vein, we might suppose an open source project developer to be more or less incited to participate in function to his own satisfaction concerning the way other team members behave.

H10: Developer satisfaction level toward OSS project team positively influences his participation level.

In the same way that financial incitations are likely to influence developer participation [13], other variables than those which are psychological *a priori* such as

[1] In October 2008, the project was awarded the « Project of the month » on SourceForge.org (see http://sourceforge.net/projects/concretecms)

attitude and *involvement* are worth being considered as additional moderating factors. Firstly, knowing that most of OSS team members play more a role of active users than real programmers [5] it is necessary to take into account community member diversity in our analysis. In function to their own experience, competence and their recognition by peers, open source participants are qualified with a status corresponding to a particular level of responsibility in the project achievement (subscriber, user, administrator, etc.). The role an OSS team member is supposed to play because of his status can be hypothesized as influencing his effective participation level. In particular, a developer might be incited to work on a project in which he is not very motivated because of the moral duty implied by his status. Based on this sort of conjecture, Roberts *et al. [13]* formulated the hypothesis (p. 988) that developer incentives to participate to an OSS project in terms of status enhancement would be negatively associated to his intrinsic motivation. In accordance with the way we conceptualised our research model, we might translate this hypothesis in terms of the potential influence of developer status on *attitude* and *involvement*. However, because authors have not confirmed the hypothesis in their empirical analysis (p. 994), we prefer to be apart from any assumption of a direct influence of the status on psychological antecedents up to participation level.

H11: Developer status level positively influences his participation level in the OSS project

B. Data collection

A large section of OSS studies is focused on case studies dealing with well-known OSS projects such as Linux, Apache, Red Hat, etc. e.g. [88],[89],[13],[42]. While illustrative, they are not representative of open source projects [90] where variance in terms of innovative objectives, team compositions etc. is likely to support or disapprove of the results from previous OSS results. We preferred to carry out a quantitative analysis on a sample of open source projects. Data was collected from the SourceForge website. We choose SourceForge primarily because it is the world's largest Open Source software development web site. By July 2005, SourceForge had hosted more than 124,900 projects and had more than 1,3 million registered users. Secondly, the mission of SourceForge is to enrich the open source community by providing a centralized infrastructure for developers to control and manage OSS development (managing projects, issues, communications, and code). Thus, SourceForge provides these projects with a standard technology toolset, reducing variance in developer behaviour that may be due to differences in technology used to support workflow, code distribution, and versioning.

An early survey included open-ended questions asking project administrators about the way code is developed. Administrators of the 100 most downloaded SourceForge projects were contacted by e-mail - 34 administrators completed the questionnaire. Qualitative data collected was used to develop the wording of social and individual incentives, developer behaviours items to be included in a second survey and performance satisfaction outcomes for hypothesis testing. A different set of projects was targeted for the second survey. We selected projects from one category on SourceForge: Software development (code generator, design, and framework). We limited the sample to one similar domain - enterprise application development - to control differences across projects in very different product categories. Having selected the categories, we ensured that projects had had some activity in the previous weeks in terms of contribution to the code repository, requests for bug-fixes, support, patches or features, or in terms of page views [4]. In total, 50 projects met all criteria. A subset of these projects was randomly selected to pilot test the survey. In each project we selected the member of the project whose role/ position was stated as that of developer. For the pilot test, we targeted developers who were asked to complete all scale items and answer open-ended questions, asking if any of the items were unclear, if they had problems understanding or answering any questions, or if there were ways the survey itself could be improved. Twelve developers responded, and none of them indicated any problems in the survey. Personalized invitations were sent to the remaining developers in the sample requesting their participation. We asked participants to help us understand which elements influenced the developer's performance and we offered to communicate the results of our study. In all, 92 developers responded to our survey from a sample size of 310 (an overall response rate of 29.7%). We eliminated 8 responses because these respondents wished to receive financial retribution for participating in the OSS project.

C. Variable measures

Most of our measurement instruments used previously developed scales from academic research (see table 2 in appendix). A literature review was conducted to locate past operational measures of the constructs under investigation and groups of questions were compiled from validated instruments to represent each construct. The wording of the identified measures was modified to fit the OSS context to be studied. As discussed earlier, we conceptualized developer behaviour relying on *attitude - involvement* and *participation*. For measuring the *attitude* and *involvement* variable, the two scales developed by Barki and Hartwick, 2004 were adapted. We used a nine-item scale of *involvement* (along with two subscales containing 5 and 4 items assessing the dimensions of importance and personal relevance respectively) and a four-item scale of *attitude*. While the scales developed by Barki & Hartwick [91] to measure these variables were tested in different contexts of Information System Development, they are mainly related to users and do not reflect the particular characteristics of OSS projects. Therefore, to measure *participation* in OSS projects we used the list of activities defined by Zhao & Deek [92]. Their participation measure identified 7 items: find bugs, find usability problems, suggest new features, review and inspect source code, submit source code, offer project administration assistance, and documentation. These different activities were confirmed by our key informants.

IV. Results

In order to support result validity we used the two analytical steps of PLS analysis [93]: (1) the measurement model which includes the reliability and discriminant validity of the measures and (2) the measurement model disclosing explicit and latent relations between factors. For each item, AVE is higher than 0.5 and Crombach Alpha is higher than 0.72 (see table 4 in appendix) and can be considered as suitable [94]. An additional confirmation of the viability is delivered by *composite reliability* (CR) values of confirmatory factorial analysis. This measure is frequently used to test a model's validity [95] and all values being higher than 0.82 confirm the internal validity of our constructs. For more details about data analysis results, see the appendix tables of latent variable correlations, loading and weight measures (table 5) and structure model values (table 6). Results provided by PLS analysis were refined from non significant relationships (those with |*t-statistic*|< 1,3) to present an uncluttered picture (see figure 1). Straight arrows represent hypothesized relationships confirmed by data analysis. Latent relationships between variables not predicted in our research model are represented by dotted arrows.

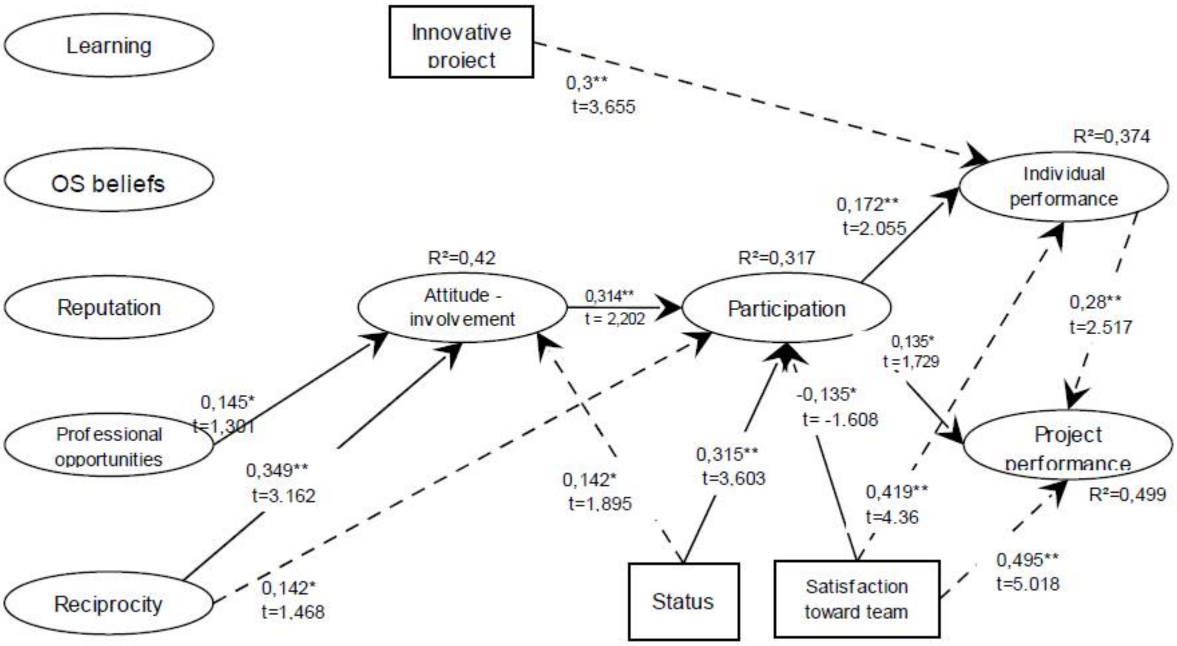

Fig. 1 : Analysis results

TABLE 1:
HYPOTHESIS VALIDATIONS

Hypothesis	Results
H1: developers' *attitude* and *implication* toward OSS projects positively influence their *participation* level.	Confirmed
H2: expected learnings positively influence developers' attitude and involvement in OSS projects.	Not confirmed
H3: open source beliefs positively influences developers' attitude and involvement in OSS projects.	Not confirmed
H4 : reciprocity motivation positively influences developers attitude and involvement in OSS projects.	Confirmed
H5: reputation motivation positively influences developers' attitude and involvement in OSS projects.	Not confirmed
H6: expected professional opportunities positively influence developers' attitude and involvement in OSS projects.	Confirmed
H7: developers' participation positively influences individual performance.	Confirmed
H8: developers' participation positively influences project performance.	Confirmed
H9: Innovative objective of the OSS project positively influences developer attitude and involvement.	Not confirmed
H10: developer satisfaction level toward OSS project team positively influences his participation level.	Confirmed
H11: developer status level positively influences his participation level in the OSS project.	Not confirmed

As stated in figure 1, the model explains 42% of developer *attitude* towards and *involvement* in OSS projects. Psychological antecedents to participation are mainly explained by *expected reciprocity* (0.349 with very high significance level) and *professional opportunities* (0.145). These results confirm hypothesis H4 and H6 while hypotheses H2, H3 and H5 are rejected. Contrary to our suppositions, developer status influences developer *attitude* and *involvement*. However, the *innovative objective* of the OSS project does not constitute a decisive influencing factor and hypothesis H9 is rejected.

Developer *participation level* is explained in the model as around 32% of the variance. As expected, the *attitude-involvement* factor represents a significant antecedent with a 0.314 weight of influence and hypothesis H1 is confirmed. PLS analysis also highlights a direct influence of *reciprocity* on *participation level* which provides an additional illustration of the significance of this variable on developer behaviour. Concerning moderating variables, *developer status* exerts a 0.315 weight confirming our hypothesis H10. However, contrary to our suppositions, the *satisfaction level toward OSS team* has a negative influence of -0.135 (hypothesis H11 is rejected).

Concerning the developer *individual satisfaction* outcome (professional know-how, knowledge acquired, etc.), the model accounts for more than 37% of the global variance. Contrary to our expectations, with a 0.172 coefficient, *developer participation level* turns out to be the lowest influencing factor. Hypothesis H7 is confirmed anyway, but *innovative project* (coefficient of 0.30) and *team satisfaction* (coefficient of 0.419) are the most statistical significant variables.

As to *project performance* (estimated through satisfaction toward progress results, achieved objectives), almost 50% of the variance is explained by the model. Here again, while hypothesis about positive influence of participation level (H8) is confirmed with a 0.135 coefficient, it remains the lowest explaining factor revealed by the PLS analysis. More significance could be attached to the 28% weight directly exerted by *individual performance* and above all, to the very important influence of *team satisfaction*: 49,5%.

V. Discussion

Our research presents classical limits inherent to the analytical methodology used and the hypothetical deductive approach. At the same time, this constitutes potential challenges for future investigations to use other data collection methods in order to better apprehend the open source phenomenon complexity. Our sample, limited to SourceForge hosted business projects, reduced the spectrum of potential behaviour in the open source community as a whole. Moreover, the analysis delivered a “one shot result” at a specific time and did not allow a longitudinal study of the way research objects evolved over time.

Nevertheless, our results offer additional insights to OSS developer behaviour, individual benefits gained from participation and, project performance outcomes. Not limiting behaviours to straightforward effective participation level and expanding the concept to *attitude* and *involvement* psychological antecedents, the article put forward some singular results compared to prior research on the influence of motivational factors. Firstly, developer adherence to open source beliefs does not appear as a decisive factor. With regard to this point, our observations do not confirm those of Stewart and Gosain [4] who stated that these open source ideology components were a determinant of team behaviour and effectiveness (p. 13). Our results are all the more significant in that we used exactly the same questions and measurements in the survey as the authors (see Appendix and p. 23 of their article). Based on the literature concerning potential drawbacks associated with intrinsic motivations [96], [97], we can consider that adhering to some beliefs can incite OSS members to multiply their participation in several projects and, as a result, reduce their marginal adhesion to each project. This scientific indetermination gives evidence to the fact that ideological principles can remain introverted or unexpressed for individuals [98] and that more thorough research using more adapted methodology analysis should be carried out to be able to apprehend psychological and sociological process complexity.

Contrary to our suppositions, we did not identify any effect of learning motivation and reputation gains toward peers on developer attitude and involvement. These results tend to be left out of classically accepted considerations in open source community literature [7],[9],[5] on the principal individual motivations of developers. In a certain sense, we are in line with Roberts et al. [13] who observed in their empirical analysis a similar result with regard to intrinsic motivation of Apache project contributors. A possible way to interpret our results (like the ones of Roberts et al.) lies in the developer sample. Having limited open source projects to those reserved for corporations can imply that surveyed participants have a profile of experienced developers who have gone beyond the state of novice programmers eager for recognition from peers because of their contributions to bug fixing on general public applications. They are often, at the same time, users (the syndrome Raymond called “scratching an itch”). We can guess that they are more advanced developers (1) still having a satisfactory reputation in the community and (2) not being in the same individual development area.

Concerning the first assertion, the result according to which *developer status* jointly influences his *attitude, involvement* and *participation level* can be considered as an additional illustration that developer active behaviour is a function of his existing recognition toward peers (and not the expected one). In other words, the more the person is, because of his status, engaged in the open source community, the more his behaviour toward the project is positive. This corroborates Roberts' *et al. [13] r*esearch and expands those of Lerner & Triole [71]. Concerning the second assertion, the result according to which *professional opportunities* appear as the unique significant motivation, incites us to figure out a potential graduation between *learning, reputation* and *professional* expectancies. Formerly, literature on open source looked for the most dominant incentive factors among those identified. More recently, researchers have studied latent linkages between them. Today, our results lead us to reflect upon some future investigations regarding their sequences over time.

The article also suggests that social motivations are focused on *reciprocity* (the most influencing factor both on *attitude-involvement* and *participation*). Empirical results of PLS analysis differ from McLure Wasko & Faraj [66] who did not identify any influence of reciprocity motivation on participant contribution. This highlights the way developers surveyed stimulated expected behaviour of other participants: contributing to the project in order to incite other developers to do the same. In other words, in terms of social motivations, implication and actions of developers seem to be mainly guided by a "giving example" wish to incite similar active behaviour in potential contributors.

If, in our article, *reciprocity* does not sound like a one to one exchange but rather a collective form of cooperation between people sharing the same focal points, we might consider that the concept meets team member's interdependencies. However, contrary to the formulated hypothesis, collected data reveals a negative effect of developer satisfaction towards the team on his own participation level in the project. This surprising result constitutes nevertheless an additional contribution to the results of Lakhami & Von Hippel (2003) who had also been surprised previously to find that no impact had been exerted by team satisfaction on the OS community. We can interpret this result by coupling it with the aforementioned one. Firstly, if the main individual motivation to participate in an OSS project is showing the right way to behave to other members and capturing their active participation (*reciprocity* variable), then a high activity level of the team itself can tend to reduce the marginal participation of developers' surveyed. In other words, the more satisfied the developer is about team project activity, the lower the participation level in the project he can afford. This reasoning is all the more acceptable in that our results suggest project performance as being less explained by developer participation level than by team effectiveness.

A similar observation can be kept in mind as regards the weak influence of developer participation in his own individual performance. This result can be interpreted from the research of Hemetsberger & Reinhart [75] who highlighted the knowledge construction process on innovative open-source platforms. According to the authors, knowledge creation must be distinguished from *learning facts*. They show how platform participants (especially new entrants) might develop competence through *transactive group memory* (p. 208) which refers to project knowledge archives (codes, CVS, stored communications, etc.) where hypertext articulation allows users contextual and intuitive explorations. In other words, knowledge and competence creation in the open source community would be possible through observational behaviour without active participation being necessary. This reminds us of how the learning process covers an abstract dimension on which individuals construct their logical mental model through reassembling information from their own experience and observations [99]. Complementary investigations could be carried out on the way OSS project participants combine active and passive behaviour such as knowledge construction processes.

VI. Conclusion

At a managerial level, the potential contributions of this article can be summarized as follows. If more and more corporations resort to the open source community to outsource IT application developments which up to now were performed by computer services firms, then project initiators need to be able to identify managerial specificities associated with the OSS community "invisible workforce" [1]. Our observations tend to put into question some truisms about the incentives to be used to motivate developers freely contributing to software development. The open source community is often amalgamated to hosting platforms for freelance developers eager for technological challenges. Our results showed that to capture and maintain a sufficient participation level in the OSS project, managers would probably find it worthwhile to stimulate open source team dynamism and effectiveness instead of simply using individual incentives.

At a scientific level, the article offers an approach conceiving individual behaviour through the lenses of the *Theory of Planned Behaviour* and the *Social Cognitive Theory*. This theoretical conceptualization allowed us not to confine developer behaviour to his/her sole effective contribution to OSS project achievement and also took into account socio-psychological antecedents to the action (*attitude* and *involvement*). We have been able to refine behavioural effects associated to motivational factors so far accepted in existing literature. However, the insignificance of both *learning motivation*, and *expected reputation toward peers* put into question a great deal of prior empirical analysis results. In the same vein, the major influence of *team activity* on both performance variables of our model incites us to reason more in terms of OSS teams than in terms of participants alone.

While the open source community is now heading for more professionally based practices, developers not concerned by financial retributions can also present a different profile than the one commonly accepted. So far, research on open source has mainly tried to identify intrinsic and extrinsic motivation factors to be stimulated in order to ensure that the OSS project be not abandoned before a first version has been published. Future investigations would be interesting in terms of open source governance [100] in order to explore how an open source project initiator could efficiently manage the OSS project team as a whole.

VII. References

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VIII. Appendix

TABLE 2:
CONSTRUCTS AND THEIR MEASURES

Constructs	Based on...	Definition /Main items used
Attitude - Involvement	Barki & Hartwick, 1994	*Measured with a 5 point osgood scale:* I believe my involvement in the OSS projects is: • Non essential________________Essential • Trivial_____________________Fundamental • Insignificant________________Significant • Unimportant________________Important • Not needed_________________Needed This OSS project: • is irrelevant to me____________is relevant to me • no concern to me_____________concern to me • does not matter to me_________matters to me • means nothing to me_means a lot to me My attitude toward the OSS projects is: • Usefullness_________________Useful • Bad________________________Good • Worthless__________Valuable • Terrible_____________________Terrific
Participation	Barki & Hartwick, 1994	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* Find bugs Find usability problems Suggest new features Review and inspect source code Submit source code Offer project administration assistance Documentation writing
Learning motivation	Gray & Meinster, 2004	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* I'm willing to select a challenging work assignment of the OSS platform that I can learn a lot from I often look for opportunities in OSS to develop new skills and knowledge I enjoy challenging difficult tasks in OSS development where I'll learn new skills
Reputation gain motivation	Kollock, 1999	Through my contributions to the OSS, my colleagues I work with respect me My contributions to the OSS project improves other's participants recognition of me My contributions to the OSS project improves my recognition by the open source community
Social relationship	Bandura, 1995	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* My contributions to the OSS project would strengthen the ties between existing members and myself. Contributing to the OSS project would get me well-acquainted with new members of the community My contributions to the OSS project would expand the scope of my association with other members. My contributions to the OSS project would draw smooth cooperation from outstanding members of the OSS project in the future.
Professional opportunities	Davis, 2003 Venkatesh et al., 2003	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* Working on the OSS project would facilitate my professional daily work. Working on the OSS project would improve my programming skills. Working on the OSS project would enhance my career advantages. Working on the OSS project would enhance my professional job effectiveness.
Open source software ideology	Stewart & Gosain, 2006	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* I believe that the best code wins out in the end I believe free software is better than commercial software I think information should be free I believe that with enough people working on a project, any bug can be quickly found and fixed.
Team satisfaction	Crawston *et al.,* 2006	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* I'm satisfied with the contributions of the team members I'm satisfied with the team's effort to achieve the project objectives

Individual satisfaction level	Hogg & Terry, 2000 Kankanhalli, 2005	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* Replication - I now have a much better understanding of the right way to do my work that I did before joining the OSS project, - Compared to before joining the OSS, I now know much more about proven methods and procedures Adaptation - I have been revising and adapting my knowledge to keep up with changes in versions in the OSS project - New developments in the OSS project have caused me to revisit and update my knowledge Innovation - I have been very innovative in my thinking since my involving this OSS project - Since joining the OSS project, I have thought of some revolutionary ways that my job could be improved.
Project satisfaction level	Crawston *et al.,* 2006	*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* - I'm satisfied with the results achieved from the project to date - I'm satisfied with progress achieved within this project - This project achieved its goals
Innovative OSS project		*Measured with a 5 point likert scale (1 = strongly disagree; 5=strongly agree):* Development of this OSS project requires pioneering innovation. The OSS project I am involved in is complex to develop We have to use non-routine technology to develop this OSS project
Status		*Each symbol above corresponds to a member status on SourceForge* Which of the following symbols best describes your role within the OSS community?  (open source project administrator)  (SourceForge.net site administrator)  (SourceForge.net user and donor)  (user who have become SourceForge.net subscriber  (user who have become SourceForge.net subscribers and have also made a donation to the site)  (user who have opted-in to receive donations via the SourceForge.net donation system)  (users who have made a donation to the project)  (administrator on the project and who have also made a donation to this project)

TABLE 3:
CONSTRUCTION SUMMARY

Construct	Label	Composite Reliability	AVE	Alpha de Cronbach
Participation	PARTICIP	0.869104	0.571374	0.834532
Reputation	MOT_REPU	0.871488	0.631168	0.838123
Learning	MOT_APP	0.92515	0.804767	0.89827
Team satisfaction	SAT_EQP	0.948617	0.90226	0.912981
Professional opportunities	MOT_PRO	0.871405	0.629504	0.839224
Reciprocity	MOT_RECI	0.923395	0.75098	0.908195
Attitude - Involvement	ATTI_IMP	0.930393	0.527894	0.944016
OS belief	MOT_IDE0	0.848586	0.584286	0.804373
Project satisfaction	PERF_PJT	0.926725	0.808904	0.898854
Individual satisfaction	PERF_IND	0.910154	0.631072	0.898634
Innovative project	INNOV	0.823907	0.609576	0.732912

TABLE 4:
MEASURE SUMMARY

	Entire Sample Estimate	SubsampleMean	Standard Error	T-Statistic
SAT_EQP->PERF_IND	0.419	0.3909	0.0961	4.3599
MOT_IDE0->ATTI_IMP	0.052	0.1015	0.0743	0.7003
MOT_APP->ATTI_IMP	0.084	0.1209	0.0893	0.9409
MOT_REPU->ATTI_IMP	0.062	0.1259	0.0984	0.63
MOT_PRO->ATTI_IMP	0.145	0.1434	0.1114	1.3014
MOT_RECI->ATTI_IMP	0.349	0.3571	0.1104	3.1623
ATTI_IMP->PARTICIP	0.314	0.3214	0.1426	2.2017
SAT_EQP->PERF_PJT	0.495	0.4722	0.0986	5.0178
STATUS->ATTI_IMP	0.142	0.1487	0.0749	1.8954
STATUS->PARTICIP	0.315	0.2978	0.0874	3.6034
INNOV->PERF_IND	0.3	0.3181	0.0821	3.6552
MOT_RECI->PARTICIP	0.142	0.1541	0.0967	1.4681
PARTICIP->PERF_IND	0.172	0.1912	0.0837	2.0554
PARTICIP->PERF_PJT	0.135	0.1362	0.0781	1.7293
PERF_IND->PERF_PJT	0.28	0.279	0.1113	2.5167
SAT_EQP->PARTICIP	-0.126	-0.126	0.0783	-1.6082
INNOV->ATTI_IMP	0.065	0.0909	0.0639	1.0174

TABLE 5:
MEASUREMENT MODE (LOADING AND WEIGHTS)

		LOADING				WEIGHT			
		Entire Sample Estimate	Mean of subsamples	Standard error	T-Statistic	Entire Sample Estimate	Mean of subsamples	Standard error	T-Statistic
PARTICIP	R29	0.8196	0.8119	0.0466	17.5944	0.2613	0.2619	0.0425	6.1554
	R30	0.7695	0.7683	0.0604	12.7384	0.2975	0.2964	0.0544	5.4702
	R31	0.7386	0.7428	0.0553	13.3605	0.2574	0.2591	0.0333	7.7329
	R32	0.7677	0.764	0.0578	13.2752	0.2837	0.2886	0.0452	6.2732
	R33	0.6768	0.6604	0.096	7.0524	0.2202	0.2118	0.0509	4.3276
MOT_REPU	R17	0.8491	0.8288	0.0682	12.4434	0.3104	0.3075	0.0598	5.1906
	R18	0.6988	0.6529	0.1617	4.3209	0.2649	0.2447	0.0797	3.3239
	R19	0.882	0.8885	0.031	28.4396	0.379	0.4089	0.0871	4.3535
	R20	0.7332	0.7206	0.0943	7.7763	0.2961	0.292	0.0917	3.2292
MOT_APP	R10	0.9134	0.9178	0.0203	44.9765	0.4345	0.4431	0.0615	7.0697
	R11	0.8688	0.8535	0.0675	12.8618	0.2876	0.276	0.0684	4.2046
	R12	0.9084	0.9075	0.0512	17.738	0.3889	0.3884	0.0611	6.3639
SAT_EQP	R59	0.9431	0.9371	0.0313	30.1735	0.4911	0.4888	0.0288	17.055
	R60	0.9567	0.9564	0.0124	76.8563	0.5611	0.5662	0.0427	13.1554
MOT_PRO	R13	0.7512	0.7371	0.0817	9.1902	0.2654	0.2583	0.0842	3.1526
	R14	0.7477	0.7323	0.1055	7.085	0.3282	0.3257	0.0852	3.8541
	R15	0.8293	0.8228	0.0729	11.3795	0.3483	0.355	0.0735	4.7405
	R16	0.8408	0.8324	0.0741	11.3465	0.3169	0.3221	0.0761	4.1656
MOT_RECI	R21	0.8806	0.8772	0.0303	29.0792	0.3177	0.3182	0.0348	9.1248
	R22	0.858	0.8468	0.0559	15.3549	0.2511	0.2428	0.0353	7.1095
	R23	0.8946	0.8941	0.0281	31.8896	0.283	0.2849	0.0234	12.1018
	R24	0.8319	0.8363	0.037	22.5124	0.3025	0.3103	0.0394	7.6809
ATTI_IMP	R38	0.7537	0.7595	0.0516	14.6016	0.1312	0.1415	0.0334	3.9294
	R39	0.7484	0.7484	0.0773	9.6797	0.119	0.1238	0.0258	4.6205
	R40	0.7034	0.7017	0.0899	7.8278	0.1166	0.1231	0.0316	3.6957
	R41	0.666	0.6579	0.0968	6.8775	0.1074	0.1147	0.0306	3.5105
	R42	0.7296	0.6957	0.1161	6.2834	0.1103	0.1068	0.028	3.9353
	R43	0.7434	0.7189	0.1004	7.4041	0.1213	0.1206	0.0287	4.2303
	R44	0.7667	0.7302	0.1194	6.4192	0.1211	0.1136	0.024	5.0356
	R45	0.7518	0.7251	0.112	6.7124	0.1121	0.1089	0.0264	4.2423
	R46	0.7511	0.7229	0.1012	7.4244	0.1016	0.0998	0.0171	5.9267
	R47	0.6092	0.5858	0.1624	3.751	0.0801	0.0793	0.0276	2.9017
	R48	0.7687	0.7484	0.0906	8.4807	0.1178	0.1208	0.0209	5.6453
	R49	0.71	0.7015	0.078	9.1053	0.134	0.1392	0.0327	4.0982
STATUS	Us_adm	1	1	0	0	1	1	0	0
MOT_IDE0	R25	0.8124	0.811	0.1268	6.4053	0.4349	0.5134	0.2087	2.0835
	R26	0.7205	0.6584	0.171	4.2144	0.275	0.2615	0.1418	1.9393
	R27	0.7208	0.6322	0.2096	3.4387	0.2888	0.2827	0.1487	1.9426

	R28	0.799	0.7102	0.2066	3.8668	0.3008	0.2819	0.1353	2.2224
PERF_PJT	R56	0.9331	0.9315	0.0217	43.0031	0.3808	0.3788	0.0204	18.6858
	R57	0.943	0.9418	0.0154	61.3745	0.4077	0.4097	0.0281	14.5153
	R58	0.8166	0.8143	0.0498	16.4092	0.3187	0.3201	0.0316	10.0963
PERF_IND	R50	0.8382	0.8348	0.0391	21.4521	0.2176	0.2235	0.0313	6.9586
	R51	0.8766	0.8774	0.0241	36.3741	0.2357	0.245	0.0334	7.0644
	R52	0.826	0.8237	0.0444	18.6169	0.2204	0.2191	0.0201	10.9415
	R53	0.818	0.8049	0.0557	14.6819	0.1984	0.1895	0.0306	6.4796
	R54	0.7793	0.7703	0.0646	12.0612	0.2215	0.2218	0.0213	10.4067
	R55	0.5973	0.5877	0.0966	6.1835	0.1574	0.1571	0.0285	5.5231
INNOV	R61	0.7993	0.7527	0.1215	6.5783	0.4649	0.4285	0.1032	4.5034
	R62	0.798	0.7964	0.0602	13.2646	0.4186	0.4308	0.0951	4.4005
	R64	0.7437	0.753	0.0661	11.2443	0.3958	0.4224	0.0791	5.0063

TABLE 6:
Structure model

	Entire Sample Estimate	Mean of subsamples	Standard error	T-Statistic
SAT_EQP->PERF_IND	0.419	0.3909	0.0961	4.3599
MOT_IDE0->ATTI_IMP	0.052	0.1015	0.0743	0.7003
MOT_APP->ATTI_IMP	0.084	0.1209	0.0893	0.9409
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STATUS->ATTI_IMP	0.142	0.1487	0.0749	1.8954
STATUS->PARTICIP	0.315	0.2978	0.0874	3.6034
INNOV->PERF_IND	0.3	0.3181	0.0821	3.6552
MOT_RECI->PARTICIP	0.142	0.1541	0.0967	1.4681
PARTICIP->PERF_IND	0.172	0.1912	0.0837	2.0554
PARTICIP->PERF_PJT	0.135	0.1362	0.0781	1.7293
PERF_IND->PERF_PJT	0.28	0.279	0.1113	2.5167
SAT_EQP->PARTICIP	-0.126	-0.126	0.0783	-1.6082
INNOV->ATTI_IMP	0.065	0.0909	0.0639	1.0174