The periphery on stage:

The intra-organizational dynamics in online communities of creation

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Abstract

This paper theorizes the intra-organizational dynamics of online communities of creation such as Free and Open Source software projects. It describes the role of the participants at the peripheries of these online communities and analyzes how the division of labor among peripheral and core members is handled. The paper further demonstrates that this mode of labor division is possible only if the periphery is able to acquire and absorb the standards associated with the developers' activities, described here as a social practice. We describe how the propagation of such standards takes place through non-material artifacts such as code and virtual discussions. We show that because of the capacity of these artifacts to effectively disseminate the standards of a social practice, such standards can be transferred not only face to face, but also asynchronously, asymmetrically and openly.

Key Words*: free/libre/open source software, periphery, core, practice, inscription, artifact, standards*

1 Introduction

Innovation in online communities of creation depends on the contributions of skilled individuals. For sensible, cumulative, and valuable contributions to coalesce in an innovative product, a community needs to expand beyond the founders' vision of a project (Krishnamurthy, 2005; Comino, Manenti, Parisi, 2007). While a lot of research has gone into basic functioning and the role of incentives in communities of creation, such as those that have developed out of Free and Open Source software projects (Sawhney and Prandelli, 2000; Lerner and Tirole, 2002; Bonaccorsi and Rossi, 2003; Roberts, Hann, Slaughter, 2006; Baldwin and Clark, 2006), much less is known about the internal dynamics of such communities. New members join (von Krogh, Spaeth and Lakhani, 2003) and progress toward membership within the core group of participants (Dahlander and O'Mahony, 2011), yet they emerge from a larger collective of individuals in these communities: the periphery. We ask: how does the periphery function, grow, and relate to the community's core? We contribute to a better understanding of the division of labor between the periphery and the core as part of a shared social practice, and we theorize the propagation of standards that define the social practice through non-material artifacts such as code and online discussions.

Building on the work of Sawhney and Prandelli (2000), we define communities of creation as online communities that are composed of individuals and firms that share a common interest, a sense of belonging, a shared language, rules for participation and governance, mechanisms to manage intellectual property rights, and an explicit purpose for the cumulative creation of knowledge. Such communities co-create projects that culminate in a wide range of products such as software, toys, jewelry, music and more (O'Mahony and Ferraro, 2007; Hienerth et al., 2011; Füller et al., 2011; Jarvenpaa and Lang, 2011). Communities of creation stand in clear contrast to other online communities that lack the purpose of collective creation, such as communities of consumption that celebrate brands or share consumption experiences (Algesheimer et al., 2005; Cova & Pace, 2006; Kozinets, 2007; McAlexander, Schouten, & Koenig, 2002; Schau & Gilly, 2003). Communities of creation are conceptually closer to of the idea of a community of practice (Wenger, 1998a, 1998b) or an epistemic community (Cowan, David and Foray, 2000) in the shared trait of a social space, in which the production of knowledge and social processes that regulate

interaction are tightly interwoven. As Amin and Cohendet (2004) argue, communities such as those formed by the Linux developers, one of the most sophisticated and established communities of the open source software world, are in between these two last typologies, embodying a unique combination of the two. We will analyze this case in depth, focusing on the community of practice perspective. Specifically, we define members on the periphery of online communities of creation based on two unambiguous characteristics: level of contribution and access to joint resources. First, the contributions to a typical community of creation, for example, the Free and Open Source software (FOSS) development community, are distributed according to a power law (Krishnamurthy, 2005; Maillart et al., 2008) and thus allow for a clear distinction between core and peripheral contributors. Second, many communities of creation assign rights of access by which participants can directly modify the co-created product. In the FOSS community, this results in the distinction between those members with writing access to the source code and the other features of the project for core members, whereas peripheral contributors need to have their contributions checked by a core member before the code contribution enters the project (O'Mahony, 2003; Lee and Cole, 2003). Note that the levels of contribution differ along two sets of data: communication and code. Access to communication resources may be more open than write access to source code repositories. A joint analysis of these access channels can thus lead to the identification of a clear core-periphery distinction.

This distinction is useful because the aim of this paper is to describe how communities of creation share a social practice with their periphery—one of the least studied collective actors in online communities of creation. Peripheral members, those who orbit around FOSS projects and contribute only sporadically with bug reports, suggestions, comments, or, notably, critical expertise, are fundamental for innovation (Raymond, 1998; Lee and Cole, 2003; Dahlander and O'Mahony, 2011). However, the literature has looked at their roles without trying to theorize the dynamics of their activities and their significance for the community as a whole.

The periphery is where socialization into the community happens, where lurkers "de-lurk" through a first visible activity, and where computer-mediated communication may establish a shared practice that allows for lateral authority to emerge (Dahlander and O'Mahony, 2011), coordination to set in (Bonaccorsi and Rossi, 2003) and motivation to flourish in the context of collaborative innovation (Hertel, Niedner, Hermann, 2003; von Krogh, Haefliger, Spaeth, Wallin, 2012). In this paper, we apply a social practice perspective to

determine how development, communication, and coordination practices are shared and how intra-organizational dynamics connect members of the core with members of the periphery for the purpose of joint innovation.

Collaboration in online communities is fragile (Gächter, von Krogh, Haefliger, 2010) and may not result in generative interactions (Faraj et al., 2011). When collaboration is productive, it involves interaction between the core and the periphery, and crucially, it activates non-contractible resources and inflow from outside the organization (Faraj et al., 2011), mainly via the periphery. Members of the core spend significant amounts of time and energy to create artifacts that reflect their passion for generating a new product in a workable draft, a credible promise upon which others can build (Lerner and Tirole, 2002). The others who contribute their energy, creativity, and passion begin at the periphery. It is here that our theorizing starts and where lateral authority in organizations is first established and empirically identified. The periphery is the manifestation of community growth and inflow of new resources that add value in terms of quantity, quality, and diversity.

We consider the non-material artifacts (Callon, 1991; Faulkner and Runde, 2010) that are produced by the core to be the vehicles through which standards that define the social practice are propagated in the organization. Standards of excellence that define what is considered to be a good and appropriate practice are inscribed in the artifacts (e.g., code and online discussions). When peripheral members encounter and read these inscribed artifacts, they are exposed to the social practice and relate to it in different ways, including the adoption and socialization of those standards. To explain how inscription and socialization work, we consider two types of non-material artifacts: software code and threaded discussions that document developers' online interactions. This allows a clearer identification of the processes that form the argument, but what is said can be adapted to other types of artifacts produced by the FOSS community and to other online communities of creation that focus on the development of products other than software, such as lexica, entertainment products, designs, or early-stage product development for physical goods (Hienerth et al., 2011; Haefliger, Jäger, von Krogh, 2010).

The practice lens (Schatzki et al., 2001; Feldman and Orlikowski, 2011) combined with Wenger's (1998a, 1998b) concept of the "negotiation of meanings" enables us to describe how peripheral members can be affected by the footprint of the practice contained in the artifacts. Consider first that the code and the discussions generated by the developers are online, asynchronous, and public, so that peripheral individuals

browsing a community's website are exposed to that community's social practice. These non-material artifacts are the result of the debates and activities of the community's core members, and they therefore represent the standards that have evolved and have been endorsed through social practice. At the same time, peripheral members may be unfamiliar with the range of opinions, working methods and solutions that accompany the artifacts, which also include problems and views that the peripheral members may be unfamiliar with and may contradict their own principles. When they approach the artifacts, peripheral members are sometimes exposed to provocative practices and debates, and they may be compelled to form opinions on the topics considered crucial by the community, a process by which they judge others' ideas and find their own visions challenged as well. The resulting process of confrontation between one's own "system of meanings" and those meanings that emerge from the discourse corresponds to Wenger's (1998a, 1998b) "negotiation of meanings." In the successful and productive cases of this process of confrontation, the standards inscribed in artifacts reemerge in the everyday practice of the peripheral members, enacting and contributing to a shared social practice (Orlikowski, 2000).

In terms of its structure, the paper develops as follows. After discussing the importance and function of the periphery, we use a social practice approach to introduce the role of standards in a social practice (MacIntyre, 1981). The third section theorizes how standards propagate through non-material artifacts that allow for a division of labor in a shared social practice, and in section 4, we set forth our conclusions.

2 The Periphery

2.1 Contribution: why focus on the periphery?

In this paper, we focus on communities of creation and study FOSS development projects as prominent examples of such communities. In this model of innovation (Lee and Cole, 2003; Kogut and Metiu, 2001), the production self-organizes around a core group of a few developers surrounded by a large periphery of community members who generally make few individual contributions, in some cases none (e.g., Kogut and Metiu, 2001), and they seldom provide significant ad hoc solutions. For example, in the case of Apache, one of the most successful and widely used open source programs, Mockus et al. (2002) show that the great majority of changes to the code were done by only a few core developers. A similar picture is presented by Lee and Cole (2003) with respect to GNU Linux, the most famous FOSS operating system.

From these studies, the literature has moved on to analyze the process that individuals may go through when progressing from the periphery to the core (Jensen and Scacchi, 2005; O'Mahony and Ferraro, 2006; von Krogh et al., 2003). Other scholars have focused on how the core organizes its activities (e.g., Giuri et al. 2010; Giuri et al. 2008). In other words, the core and/or the process to enter the core have always been at the center of the research. The periphery is most often defined in residual terms or along very specific dimensions (e.g., Crowston et al., 2006, Crowston and Howison, 2005; Muller, 2006b; Ngamkajornwiwat et al., 2008; Dahlander and Mckelvey, 2005). Even if almost every article on the issue recognizes that openness is central in the FOSS model, allowing many more individuals than those actually developing the software to spot bugs and report suggestions, research on the periphery's characteristics and on its relationship with the core remains limited. Only a few studies have focused on the many individuals in the background, and even fewer have tried to provide an analysis of their relationship with the community (e.g., Berdou, 2007; Lakhani, 2006; Zhang and Storck, 2001), despite the fact that the periphery is the necessary counterpart of the core: the latter will not be able to flourish without the former.

This claim is justified by the observation that it is the duality between the core and the periphery that enables FOSS projects to grow and innovate. The small group of core developers at the center of the FOSS community is committed to its projects and performs most of the connected actions. The periphery works in response to the core's actions, on average spending less time and energy per individual, but providing the critical input of pointing out bugs, delivering suggested improvements and making small but sometimes highly relevant ad hoc contributions. Singh et al. (2007) empirically confirm this claim, finding that for a project to be more efficient and to progress faster, both a clearly identifiable group of core developers and an active periphery are needed. The conclusion is that the features of this undeniably blurred and fuzzy agglomeration of peripheral individuals who "orbit" (Wenger, 1998b) FOSS-related projects, initiatives, and discussions are essential for the FOSS innovation model–and for any distributed innovation model (Lakhani and Panetta, 2007)— to be fully realized. Because of its significant contributions in online communities of creation, the periphery deserves further attention.

The conceptual model we present below seeks to describe the roles of the periphery and the core in their division of innovative labor (Arora and Gambardella, 1994), identifying what conditions make this division of labor possible, uncovering what processes realize these conditions, and identifying the properties of the

periphery that affect them. In doing so, we emphasize the virtual environment in which the FOSS community is immersed. This approach allows for the investigation of the specific characteristics of the periphery of the FOSS community, but it also allows for the generalization of the results, which makes this study relevant for other communities of creation whose members use a virtual environment in which to conduct their joint innovation activities.

2.2 Definition of periphery

The periphery of the FOSS community can be thought of as a set of actors who are marginally involved in the discussions, projects, and actions relative to community itself, but who are nevertheless interested in those activities, search for related information, and use the software produced by the community. They are more than simple users: they browse the community archives, observe its activities and contribute by sporadically reporting bugs, sending patches or ad hoc solutions to problems, and participating marginally in community discussions, but they are not in any other way actively involved in the community. Some of them are "lurkers," that is, observers who exhibit no visible level of activity (Nonnecke and Preece, 2000; David and Rullani, 2008).

A benchmark definition of the periphery in the FOSS context has been provided by Crowston et al. (2006). The authors define individuals as members of the core or of the periphery according to their level of activity with respect to specific operations (e.g., formally being registered as a developer, contributing above or below a certain threshold in the bug-fixing process, whether an individual is part of a clique of participants who interact frequently). Similarly, Zhang and Storck (2001) examine the number of messages sent to the community forum and identify peripheral members as those who posted less than 30 messages in the sample period. This definition is essentially different from those that identify peripheral members not on the basis of the level of their activity, but on the typology. Berdou (2007), for example, differentiates members according to the degree that their activities belong to core tasks (e.g., coding) and non-core tasks (e.g., documentation or translation).

For the purposes of the present study, we follow the first approach and define the periphery of a FOSS project as the group of participants in the project who exhibit only sporadic participation related directly to the cores' ongoing activity. Theoretically, Wenger's (1998b) conceptualization of Communities of Practice can be used to define the periphery as a "cloud" of individuals who orbit the core of the community,

comprised of developers who are deeply engaged in the community's activities. In this view, operationally the salient features by which a participant can be identified as peripheral are 1) a relatively low level of activity and 2) limited writing access, which limits rights to directly modify code and other elements of the project. To determine the type of projects that can be included in this definition, we investigate the heterogeneous ecology of the FOSS projects and thereby empirically establish the boundaries of our analysis. This strategy will allow us to clarify the types of projects to which our discussion can be applied, avoiding a one-size-fits-all approach that fails to accommodate the heterogeneity of the FOSS community. To this end, we first collected data from SourceForge, the largest repository of FOSS projects in the world. The diversity and sheer size of its project population, which includes moribund as well as very active projects, makes it a perfect empirical setting with which to establish theoretical boundaries.

We obtained the data from Notre Dame University[1] describing the characteristics of 88,682 projects registered in the period 2003-2006 (i.e., 63.1% of all of the projects registered on SourceForge before December 2007) and labeled as active in December 2007. Within this group, we isolated the projects with characteristics that are compatible with the definition of periphery provided above. First, we considered only projects with a number larger than or equal to two registered members (who were considered to be the core) to assure some level of cooperative activity among core members. Second, we defined peripheral participants as non-registered users (to ensure their limited writing access) who sent at least one forum message to the group in the last half a year (July 31st, 2006 – December 31st, 2007). Forums are one of the most easily accessible tools and therefore provide a good setting for observing the peripheral participants' activity. Third, we considered only projects with a number of peripheral participants at least as large as that of core members so as to ensure that the project has a relatively relevant periphery. To assess the other aspect of our definition, we required that the numerically relevant periphery is not very active. We thus selected only those projects that have an average number of forum messages from peripheral participants below the median of the previous sample (2.271944). The final group of 307 projects that was consistent with our definition was then compared with the rest of the population of projects. To define such reference sample we focused on

[1] We thank Salvatore Torrisi, Paola Giuri and the coordinators of the project "Productivity Estimation and Skills Assessment of FLOSS Projects," Rishab Ghosh, Paul David, Jesus Gonzales-Barahona, and W.E. Steinmueller, for granting us the access to the data in the SourceForge Research Data Archive developed and maintained by the University of Notre Dame (IN, US; see Madey G., 2009; and http://zerlot.cse.nd.edu/). See Madey (2009).

projects that were labeled active and that had at least one forum message during the last considered months of our observation period (to ensure that they had some sort of activity). We obtained 1,787 projects, of which our group comprises approximately one-fifth (17.18%).

We applied t-tests for the equality of means with unequal variances[2] and Chi-squared tests for categorical variables to isolate the role of our group of projects within the reference sample. This comparison showed that our group included projects that progressed significantly faster: even if we isolated projects of the same age as the rest (p-value above 0.5), we had more projects labeled as "production stable" (p-value= 0.000) and fewer labeled as "pre-alpha" (p-value= 0.099) at least one year after their founding (December 2007). In our sample, the number of projects at the other development stages as of December 2007, their number of downloads and files released in the following year were not clearly significantly different from those of the reference population. However, in the same period, our subsample scored significantly higher in the ranking computed by SourceForge using a formula that accounted for monthly development and communication activities (e.g., forum messages and bug tracking) and for web traffic on the project's pages. This held both in terms of the average and highest positions reached over the year (p-values = 0.000), the average and maximum scores (p-values = 0.000) and the average and highest percentiles of placement (p-values = 0.000). Moreover, the standard deviation of the ranking position of each project over the 12 months of the year was lower in our group than that of the reference sample (p-value = 0.0231), and the same can be said for the percentile (p-value = 0.030) and the score (p-value = 0.000), ensuring that our projects remained in the higher positions for a longer period.

In conclusion, the group of projects that was consistent with the premises of our analysis constituted a relevant proportion (approximately 20%) of the population of projects registered from 2003 and 2006 on SourceForge that were also active in December 2007. Moreover, it comprised the most active projects as measured by their development status and the composite ranking measures of SourceForge. It is thus a sample worth considering.

2.3 The functions and properties of the periphery

As an introduction to the functions of the periphery as we have defined it, we refer directly to the unique

[2] An analysis employing Kruskal-Wallis rank tests for equality of populations gives by and large the same results.

properties of the FOSS innovation model. The first striking feature of this model is that it does not seem to employ its resources (i.e., individuals' energies, effort and time) efficiently when considering the community as a whole. David and Rullani (2008) show that a significant number of individuals have to be reached by the FOSS production model in order for just a few of them to actually become project members or to launch new FOSS projects. Defining a scale of three levels of activity (not contributing or only doing so marginally, joining existing projects, and founding new projects), the authors observe that a move upward by one level implies the shrinking by an order of magnitude of the number of mobilized individuals. Moreover, even when dealing with the most active individuals, contribution does not last long after they have launched their first project in the early months of their participation in this virtual environment. It is worth noting that in a process where individuals self-select tasks (Langlois and Garzarelli, 2008) and where there is no overall direction by which they are able to guarantee a correlation between what is needed and what individuals pursue, this is an expected outcome (Lanzara and Morner, 2005).

Moreover, the internal order of a self-organizing system (and thus its capability to produce) is not maintained simply by imposing a hierarchical structure. In the FOSS model, authority and leadership certainly exist, but they have to be continually renewed and legitimized through specific social processes (Dahlander and O'Mahony, 2011; Mateos-Garcia and Steinmueller, 2008; Muller, 2006a, 2006b; O'Mahony and Ferraro, 2007). These activities not only cost developers energy, time, and attention, but sometimes they are also ineffective and can result in further dispersion of resources through conflicts, defections, and other issues. Even if technological, legal, and social rules, processes, and constraints can be ameliorated, the unfavorable rate between productive and available resources is unavoidable, as it springs from the very characteristics of openness and self-organization of the FOSS itself. The FOSS model of innovation is inherently dissipative (David and Rullani, 2008; Lanzara and Morner, 2005).[3]

Even in this situation, however, a minority of the mobilized resources is actually used and transformed into the engine of the community. These few individuals are the drivers of the overall activity, creating new projects, joining, managing and coordinating existing ones. For such a system to survive, the available

[3] The discussion on the features (as well as the fallacies) of this analogy with dissipative systems or structures (Prigogine and Stengers, 1984) is much wider than the scope of this paper. In this case, the term dissipation is meant to indicate only the necessity for the process to "waste" a certain amount of the mobilized resources to fuel the dynamics that keep it alive and productive. As David and Rullani (2008) also state, the reader can refer to MacIntosh and

resources must be higher than those actually used, and by several orders of magnitude. More specifically, the huge number of individuals orbiting around the center of the action that is handled primarily by core members is essential to guarantee that at least a few will engage in a progression of actions that will lead them into that center. A wide periphery is therefore a prerequisite for the existence of a core, as the latter needs to be able to draw from the former a sufficient quantity of resources to sustain its production and social processes.

Continuing with the analysis, it is possible to see that the disproportion in the number of individuals that comprise the two groups is balanced by the level of engagement they have in the community. The core is composed of far fewer individuals than the periphery, but those individuals represent the engine of community activities (Krishnamurthy, 2005; Mockus et al., 2002). In the periphery, a huge number of individuals undertake activities that are on average less demanding than those taken on by core members. In the FOSS innovation model, however, these activities turn out to be crucial. The openness of the code, i.e., its modularity and its easily accessible architecture (Baldwin and Clark, 2006), make it possible to establish a precise division of labor between the core and the periphery, which increases the value of the contributions coming from the periphery. Individuals at the periphery, even if minimally active, can engage in many micro-tasks at very low cost. Finding bugs in the code is a very good example of such a micro-task (Kogut and Metiu, 2001). The large number of people in the periphery ensures that the overall level of activity is high even if each individual performs only very simple and low-intensity tasks. This process has been exemplified by the famous Linus' Law reported by Raymond (1998): "Given enough eyeballs, all bugs are shallow."

This process, however, is more complex and subtle than the previous simple formulation suggests. Lakhani and von Hippel (2009) have shown that the development of one of the most important FOSS applications, PostgreSQL, was not performed by the core in a "pneumatic vacuum." On the contrary, the continual "interference" of peripheral members is crucial to stimulate the process and provide ad hoc solutions. The likelihood that a solution to a specific and well-defined problem would come from the periphery is high because the periphery itself is composed of a multiplicity of individuals with heterogeneous knowledge and

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MacLean (1999) for further discussion of the analogy in organization studies.

skills who are free from the mind-set built during the first phases of the problem formulation that could limit the problem-solving capabilities of the core (Lakhani and Jeppesen, 2010). As an example, consider the following description of this process in the similar context of "broadcast search.", where problems are just broadcasted to a large pool of experts that can provide their solutions. [4]

"A firm […broadcasted] problem […] was solved […] by a scientist with a Ph.D. in protein crystallography [who] applied common knowledge from crystallography to toxicology. This effect may be due to the ability of 'outsiders' from relatively distant fields to see problems with fresh eyes" (Lakhani et al., 2006, p. 10 & 12).

The possibility of involving a wide and heterogeneous periphery, and to thereby benefit from the variety and diversity of viewpoints it can provide, stems from the high level of openness assured by the FOSS licenses. In the process of FOSS development, the "center of the action" is where core members develop the project supported by the sporadic ad hoc solutions, bug reports, patches and suggestions of peripheral members. This center is the virtual place where action happens (it may be, for example, the website of a FOSS project). Openness ensures that the work being performed in the "center of the action" is visible to anyone. Moreover, it ensures that anyone can also modify or suggest modifications for the artifacts produced by that action. From the perspective of a user of the product, this means that openness allows for the changing of the technology rather than of a working routine. In his recent work on flexible technologies and flexible routines, Leonardi theorizes that users may adapt a technology rather than their working routines when they perceive constraints more than they perceive affordances (Leonardi, 2011). When browsing the code and the publicly available discourse published by the FOSS community, many developers relate to the community in passive ways, but a few others, due to the favorable ratio between perceived constraints and affordances, may instead actively contribute to the development of technology by submitting patches or modifying the software according to their needs. A heterogeneous periphery ensures a wider diversity in the constraints and affordances perceived by the peripheral members and can also easily inspire a few of them to contribute ad hoc solutions. Moreover, a greater variety of individuals populating the periphery ensures that the scope of their needs and actions will be broad enough to inspire the many features of the software (Raymond, 1998;

[4] When applying broadcast search, firms' search processes do not take place inside the firm but are developed broadcasting the problem to be solved to a wider audience of mostly unknown "outsiders". The provision of a workable

Bessen, 2006). This is crucial for the innovativeness of the model, as peripheral members who perceive constraints in their use of the software are the same developers who try to extend the functionality of the software to new domains and environments in which the software has not yet functioned properly. In other words, the periphery can provide the core not only with a large workforce that can perform activities such as bug reports, patches, production, or useful feature identification; the heterogeneity of skills allows some peripheral members to engage with the core and to enter the "center of the action," providing valuable out-of-the-box ad hoc solutions.

Aside from providing a pool of future resources, the mass of beta testers, debuggers, and proponents of ad hoc solutions, the periphery also has another role: it exercises social control in the community. The periphery participates not only in the technical processes of production but also in the construction, replication, and preservation of community rules and values. Monitoring and spreading information on copyright infringement—as well as any other behavior that goes against the rules of the community—is an activity that the periphery can handle effectively. Fallacies in others' code or behavior can easily be spotted by a large community of observers that is much larger than that of the few protagonists of the development process. Moreover, as is the case for technical solutions, ad hoc stimuli relative to the social environment and culture of the community can also come from the periphery. Elliott and Scacchi (2003) report a case in which a discussion of the basic values of the FOSS community (namely, the lack of freedom associated with the use of non-free code) was triggered specifically by a member of the periphery. The periphery contributes to social control, rule compliance, and the construction of the ethos at the foundation of the community's activities[5].

For these reasons, the participants who are not mobilized in the processes that would direct them toward the core (described by Lave and Wenger, (1991) as the "legitimate peripheral participation process") are nevertheless helpful. These remaining participants serve as peripheral resources because they can perform

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solution by an "outsider" is usually compensated by a prize. See Lakhani et al. (2006) for more details on this model.

[5] The absence of formal mechanisms of control, such as contracts, raises fascinating questions as to the dynamics of social control (Ross, 1901; Shibutani T. 1955) in communities of creation. At what point in the life of a community can social control enforce solidarity or compliance to internal rules (Hechter, 1987; Fehr and Gächter, 2002)? How does the network that makes up an online community influence trust and social control (Shapiro, 1987)? For our purposes, it is here sufficient to say that the periphery is playing an active role in social control, and we thank a referee for pointing to this wider complex set of questions.

certain tasks more effectively than the core. We summarize this first point in the following proposition:

Proposition 1a (dissipation): The productive division of labor between the core and the periphery is realized due to the presence of a large number of diverse peripheral developers.

Two more properties of the periphery are worth noting. Contrary to physical space, where mere presence is already a means of interaction and a context for action, in the virtual space of the FOSS community, the act of observing others' behavior is usually not detected (Finholt and Sproull, 1990; Zhang and Storck, 2001). Members of a virtual space become visible only if they act in that virtual space (Nonnecke and Preece, 2000; Lanzara and Morner, 2005). Whoever acts at the center of the action (usually, a member of the core) is visible, while those who are only minimally active (i.e., the large majority of peripheral members) are only minimally visible, or even totally invisible. Coupling this last observation with dissipation (Proposition 1a), we arrive at the following proposition:

Proposition 1b (invisibility): In keeping with Proposition 1a, many peripheral developers are invisible observers of the community's work.

This leads to another property, atomization, which means that the periphery is a non-organized group of individuals. Most peripheral participants make their decisions based on what they observe in the center of the action, which is visible and mainly undertaken by the core, because invisibility makes impossible for them to interact with the other invisible peripheral members. This property is highlighted by Borgatti and Everett (1999), who use atomization as the defining concept for the periphery: in the core, vertexes are connected with one another, while peripheral vertexes are defined as those that relate only to the core and are not linked among themselves. A similar perspective is put forward by West and Lakhani (2008) in their analysis of the concept of community. While investigating the role of interactions between community members, the authors ask if a user community à la von Hippel (1988) can still be considered a community when user-innovators provide their innovations to the focal firm but do not interact among themselves. The problem the authors consider relates to group dynamics: being completely atomized, the social bodies they identify exhibit an aggregate behavior that is merely the sum—and not the combination—of each component's idiosyncratic behavior. This emphasis on the idiosyncratic characteristics of the periphery relates directly to the discussion on diversity we have developed above because atomization hinders group-thinking and the

convergence of points of view and thereby increases heterogeneity. As a result, invisibility (Proposition 1b) leads to atomization, which further enhances the level of diversity found in the periphery of FOSS projects. Thus, we propose the following proposition:

Proposition 1c (atomization): Due to Proposition 1b, peripheral developers are only connected to the core. This magnifies their diversity, increasing the possibility for a productive division of innovative labor with the core (Proposition 1a).

2.4 Social practice and shared standards between the core and the periphery

The innate differences between the core and the periphery stated by our first set of propositions (dissipation, invisibility and atomization) allow for a productive division of innovative labor among them (Arora and Gambardella, 1994): while the core undertakes the main activities related to the development of the project, the periphery undertakes a completely different set of activities in line with dissipation, invisibility and atomization:

> A. The periphery constitutes the pool from which the core draws the resources it needs to function. The progression by some developers from the periphery to the core ensures the continual provision of new and diverse skills, energies, and ideas to the core.
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> B. It undertakes a series of technical tasks (such as bug reports and ad hoc solutions) that can help the core to improve and develop code, thereby enhancing its productivity.
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> C. It constitutes the main mechanism through which social control (in the form of monitoring or investigating members' rule compliance) is undertaken.

However, a productive division of innovative labor can take place only if the core and the periphery can actually integrate their activities. If the contributions (such as new ideas, new code, new solutions, or news about rule infringements) coming from the periphery into the center of the action are questioned, misunderstood, or even considered to be illegitimate by the core, the division of innovative labor cannot take place. Peripheral members need to be able to produce contributions and propose them in ways that the core can understand and consider as a legitimate part of the developing process. This calls for a higher level of attention to the conditions under which peripheral members are able to participate in the project's activity.

One way to fill the potential gap between the periphery and the core in this respect is to have an intermediate organization that functions as a knowledge broker. This is the case of InnoCentive, described by Lakhani and Jeppesen (2010): a large periphery of diversified scientists becomes a resource of important novel solutions

only because InnoCentive bridges their knowledge domains with that of its clients, creating reciprocal understanding and legitimation. Another solution identified by the literature is the concept of boundary objects, i.e., "objects that are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989; p. 393). These properties allow a boundary object to serve as the interface between different communities, translating the language and legitimacy of claims from one context to another (Carlile, 2002). In the context of FOSS development, what turns out to be crucial is the process through which a shared practice is formed and the standards stemming from it are shared among all of the participants in the projects (von Krogh et al., 2012), both core and peripheral. To understand it, we analyzed shared standards as part of the social practice of developing software and the way non-material artifacts can help propagate common ways of working.

Developers of open source software create complex products in cumulative steps, building on each other's work over long periods of time without ever being physically located in the same place. Frequently, FOSS developers do not know each other personally despite having long-term working relationships. Despite the fact that their contributions are dispersed and asynchronous, they share an understanding about the technology they develop (Kuk, 2006) and about the best ways to advance the software product. This shared practice is not well theorized because it involves the transfer of tacit, experience-based knowledge that is considered to be transferrable only through high cost and physical presence (Szulanski, 2000; von Hippel, 1994; Cowan et al., 2000; Nelson and Winter, 1982).

The notion of shared practice can be defined as a collective of participants engaged in individual activity that is primarily social. This notion unites the subjective (actor) and the objective (the action) as they merge through social life (Schatzki et al., 2001; Barad, 2007) experienced in social bodies such as organizations (Feldman and Orlikowski, 2011). A social practice is thus a shared set of individual activities that are debated and understood as meaningful to the participants. MacIntyre defines a social practice with a particular view on the ethical dimension that participants aspire to by attempting to improve their practice. In his words, a social practice is "any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realized in the course of trying to achieve those standards of excellence that are appropriate to, and partly definitive of, that form of activity, with the

result that human powers to achieve excellence, and human conceptions of the ends and goods involved, are systematically extended" (MacIntyre, 1981, p. 187).

What is at stake in the division of labor in FOSS development is the building and propagation of the elements that enable the shared practice of FOSS development. Shared knowledge about technology and developing ways to improve on and create better solutions seem as important as a shared language to talk about and debate the best methods by which to build on each other's work. Giuri et al. (2010) argue that members of FOSS projects already share a wide knowledge basis and speak the same language, as they belong to the same 'hacker culture' and have skill sets that, even if differentiated in their articulation, all belong to a specific set of abilities (e.g., programming software or working in teams). The empirical analysis they conduct in this context shows that skill diversity is much more important, while it is unclear how the overlapping of team members' skills affects the productivity of FOSS projects. Even if no coordination is possible without a minimum level of mutual knowledge and common language, cooperation in the production of complex products seems to require more than just communication.

In particular, standards of excellence need to be shared by the members of the community to create a productive division of labor in the social practice. In general, standards can be conceived as guideposts, both as constraints and enablers, which shape and guide individuals' actions. Standards, however, are not a top-down construct imposed from the social level onto the individual level or from the core to the periphery. They are created in practice and through individuals' interactions and are an emergent property of collective processes. Individuals retain agency, i.e., the potential to choose a different path of action that is not in line with the social practice.

Standards guide correct and appropriate action and need to be shared by the core and the periphery to allow both sectors to effectively participate in the social practice and, at the same time, establish a division of labor. Standards include social rules, technical procedures, shared values and their interpretations and representations by the participants, aimed at guiding the social and technical processes that constitute the activities of the community. Standards serve the goal of making the joint product the best it can be. MacIntyre's characterization of the standards of excellence squares perfectly with the ethos of the FOSS community, which seeks to maintain the quality of the output of its social practice (von Krogh et al., 2012).

Standards evolve in what we have called the center of the action, and they propagate to the invisible members of the periphery. While the center of the action is not always populated only by the core, as the PostgreSQL example above showed (Lakhani and von Hippel, 2009), the core certainly has a prominent role in this process, as it undertakes the bulk of the visible work that occurs in the center of the action.

An example of a standard is the conviction widely held by members of the FOSS community that the advancement of the project comes from code contributions rather than opinions and argument. An interesting case describing this point is offered by Alan Cox's (1998) discussion of the Linux 8086 project. Cox says: "The problem that started to arise was the arrival of a lot of (mostly well meaning) and dangerously half clued people with opinions - not code, opinions" (Cox, 1998, online). Cox concludes that code confers legitimacy, a finding that is consistent with von Krogh et al.'s (2003) description of joining scripts. Valuable contributions can come from both peripheral and core members, and the center of the action can occasionally involve peripheral members. However, new or peripheral members need to heed the standards in order to be legitimated and finally heard in the center of the action, where the work is taking place and where standards evolve. It is difficult or impossible for a periphery member to significantly contribute to the social practice unless she understands that opinions without code are ignored. Hence, we offer the following proposition:

Proposition 2: The division of innovative labor between the core and the periphery is made possible by a social practice that develops standards of excellence (quality, communication) that need to be shared across the entire community.

3 The division of labor through the propagation of standards

3.1 The importance of standards and their propagation

If the core and the periphery could engage in the development of the shared practice on equal levels, and through that engagement create a shared set of standards, the division of innovative labor would be realized based on an approach that has already been widely studied in the literature of communities of practice (Lave and Wenger, 1991; Lin, 2004a; Wenger, 1998a). However, the periphery does not interact with the core from the same level due to dissipation (Proposition 1a), invisibility (Proposition 1b), and atomization (Proposition 1c). Only occasionally are a few peripheral members engaged in the activity at the center of the action and, when they are, they participate only marginally or *una tantum*. This makes the transfer of standards virtually

impossible through legitimate, peripheral participation (Lave and Wenger, 1991). Indeed, standards cannot be transferred through legitimate peripheral participation because there is no traditional teacher-apprentice relationship. However, even without direct interaction, the standards of the social practice can be propagated to the periphery through their inscription into non-material artifacts. The artifacts show what work is needed, where it can be tackled, and how to approach it (Baldwin and Clark, 2006; Dalle and David, 2005).

First, consider that standards are guideposts to higher quality work and can be seen in action and in the artifacts that document and communicate that action. Every time a developer in the center of the action mobilizes a certain resource or respects the limits imposed by a specific constraint, the standards underpinning those resources and constraints are, in a certain sense, "brought to life." In other words, the social practice, with its interactions well known and studied in the literature (Amin and Cohendet, 2004; Cohendet et al., 2001; Lin, 2003, 2004a, 2004b), is the anvil upon which the standards are forged. As a consequence, standards such as social rules, technical procedures, and the related representations and interpretations, do not exist independently of the action, but rather they are enacted by means of the practice, undertaken while developers interact.

Second, consider that artifacts are crucial factors for the construction and propagation of standards. When artifacts are produced collectively, the standards that informed their process of production are inscribed into the artifacts themselves, i.e., the artifacts' inner configuration contains and reflects the standards that emerged during their construction. For example, Lanzara and Morner (2005) show how the organizational features of the FOSS production process are inscribed into non-material artifacts such as threaded messages circulating in the projects' mailing lists and stored in online public archives. "The developer mailing lists are electronic communication artifacts inscribing software-based protocols and procedures that allow specific interactions while prohibiting others, make possible specific ways of developing software jointly, and enact specific models of organizing and knowing" (Lanzara and Morner, 2005, p. 73). The organization of the debate in threads, the constellation of different opinions and opinion leaders that emerge during the debate, and the way the interaction develops (Kuk, 2006) all reflect the ways in which standards evolve and are expressed as a central part of the practice. Similarly, code embeds the procedures and development ideas of its creators.

The consequence of the two mechanisms described above is that inasmuch as the standards are inscribed into the artifacts' configuration, the artifacts become vehicles for the standards. When individuals other than the artifacts' creators use the artifacts in their everyday practice, the objects' configurations facilitate certain actions and prevent others, making room for certain opinions and restricting others. The objects' configurations document a certain vision of the world while suppressing others. Orlikowski (1992; 2000) effectively puts forward this idea in the context of the relationship between technological artifacts and their users. She argues:

"While a technology can be seen to have been constructed with particular materials and inscribed with developers' assumptions and knowledge about the world at a point in time… it is only when this technology is used in recurrent social practices that it can be said to structure users' actions" (Orlikowski, 2000, p. 408).

Therefore, when using an artifact, users interact with the inscribed standards; the standards that were created in production reemerge during the use of the artifact. This interaction with inscribed standards happens whenever users engage with the artifact (e.g., reading the code or the messages). It also occurs when they experiment, innovate, discard opinions and form others, even if their work does not reach the center of the action of the social practice and thus has no impact on the way the social practice proceeds, and on the standards it produces. However, even in isolation, when users interact with the artifacts, a bridge is created between the core and the periphery across which standards are transferred, allowing for the division of innovative labor. This is the case even if the periphery does not share the same tasks nor the same impact on the practice as the core does.

As cited above, Lanzara and Morner (2005) describe the process of inscription in threaded mailing list messages: the core and the few peripheral members who provide sporadic ad hoc solutions and post comments in mailing list discussions (together with other non-material artifacts such as code, code documentation, comments and other forms) that are stored in publicly accessible archives. The messages reflect the standards that emerge in the practice, as they are inscribed in the configuration of discussion threads and in the web of opinions conveyed by the messages. Peripheral members access the repositories of the mailing lists when searching for information or simply looking for updates on the development process. The web of opinions, visions, and ideas that these peripheral individuals see also forms a web of constraints (e.g., through discussions delegitimizing certain set of arguments) and enabling factors (e.g., through

opinions supporting other lines of argument) reproducing the inscribed standards. When peripheral members use the artifacts, i.e., reading discussion threads when conducting an information search, they form opinions, compare their own ideas with those of others and either modify their own visions or react against those that they encounter. Through this type of interaction in their everyday practice, they engage with the inscribed set of standards. Thus, the standards are "brought to life" through the practices of peripheral individuals, even if the peripheral individuals do not regularly participate in the core's activities or take an important role in the evolution of the standards at the center of the action. What has been said for mailing list messages is also true for other artifact typologies. Lanzara and Morner (2005) develop their argument with regard to the code itself and to the licenses based on copyleft, but there is also a growing literature that discusses both how the inner configuration of the code affects the organizational features of FOSS projects (e.g., Dalle and David, 2005; MacCormack et al., 2006), and how FOSS's licenses influence the social processes taking place within projects (Gambardella and Hall, 2006). The key feature behind the propagation of standards is the engagement of peripheral members and their adherence to the standards inscribed onto the non-material artifacts associated with FOSS projects. We thus propose the following proposition:

Proposition 3: A productive division of labor between the core and the periphery is made possible by non-material artifacts that function as vehicles for standards of excellence.

3.2 The propagation of standards through non-material artifacts

FOSS's typical virtual communication is almost always mediated by computers, is asynchronous and is often stored in publicly accessible virtual spaces. This means that in the open virtual environment where FOSS is produced, code and mailing list messages are widely accessible, and the social practice of the community they represent can be easily and quickly dispersed online (Finholt and Sproull, 1990). Consistent with Orlikowski's (2000) view, the simple action of using artifacts of this type, for example, browsing the repository, studying code, reading messages, and comparing one's own beliefs with those expressed in the opinions inscribed in the messages or the procedures represented in the code, is the action that allows for the propagation of the standards that result from–and guide–the social practice.

To define this process in detail, the concept of negotiation of meanings elaborated by Wenger (1998a, 1998b) in the context of communities of practice is particularly useful. Community of practice theory has been used widely, not only in management (e.g., Amin and Cohendet, 2004; Brown and Duguit, 1991), but

also in FOSS-related studies (e.g., Cohendet et al., 2001; Lin, 2003, 2004a, 2004b). The main idea behind the concept is that the development of social bodies is based on the continuous coevolution of individual activities and the representations of the self and of the context in which they are immersed. The nexus of ties that comprise a community of practice constitutes a twofold space. On the one hand, the common space is populated by the everyday life of the community, where artifacts are produced, tasks are performed, and members interact. On the other hand, in the same space and together with those activities, individuals construct representations of the world. This last term reflects the system of meanings, the semantics through which reality is organized, filtered and made intelligible by each individual.

Each individual representation is not constructed in isolation; it also captures stimuli from interactions with the other participants in the social space in which the individual is immersed (the community). The result is that the meaning that individuals will finally give to their idiosyncratic experiences is interwoven with others' experiences and representations. As a consequence, community members modify the sense of who they are and the principles that guide their actions, informing the former with the experience they have had, and reconstructing the latter around the new features of the collective enterprise. The whole process can then be conceived of as a link connecting individual identities and social interactions through a negotiation of meanings.[6]

What we have described as propagation of standards is realized in the periphery as a negotiation of meanings between peripheral individuals and non-material artifacts triggered by an individual's exposure to the social practice. This process takes the form of an internal and reflective (Hemetsberger and Reinhardt, 2006) "confrontation" between the peripheral individual and the standards that are inscribed and conveyed by the social practice. At the end of this confrontation, in the best case the individual acquires those standards of excellence as guideposts for her behavior in the community, thus acting in a way that enables a productive division of labor. If, on the contrary, the individual feels at odds with those standards, the resulting friction can create a sense of dissonance. Dissonance, as it is used in the literature, refers to the discord among the components of an individual's identity, be they behaviors, preferences, moral values, opinions, or traits. Building on a series of different theories (e.g., Akerlof and Kranton, 2000, 2005; Higgins, 1987; Livet, 2004,

[6] To further investigate how this process could work in practice in a virtual environment, see Levy (1984), Preece (2000), and Rheingold (2000). For a wider perspective see, for example, Golden-Biddle and Rao (1997) and Tuomi

2006), Kirman and Teschl (2006) argue that dissonance results in a loss of psychological well-being. As it is used here, dissonance means that the individual suffers from a loss of well-being due to her inability to merge her own original identity with those of the community standards. Dissonance reduction can be achieved simply by leaving the community. However, this is just one possible solution. Kuran (1998) suggests that another strategy for the reduction of dissonance is dissent, defined as a case in which an individual exposes "knowledge and feelings that had tended to be concealed" (Kuran, 1998, p. 152). In such a case, the individual can decrease his or her dissonance by entering the center of the action and exposing his or her opinion to the community. This is a part of what we have referred to as "ad hoc contributions." Few but important changes to the social practice of a project come from this process. In sum, when peripheral members experience a high level of dissonance, they can move along an outward trajectory (Wenger, 1998b) and exit the community or, conversely, they can enter an inward trajectory (Wenger, 1998b), moving to the center of the action and questioning the established social practice, thereby contributing to the social practice by potentially innovating and changing its course.[7]

Let us here consider the empirical case of mailing lists. We do not mean to suggest that reading online discussions leads to acceptance of the constraints and resources defined therein. Rather, it means that the engaging nature of a fully public, opinionated, and evolving social practice allows for the propagation of standards to be inscribed in the opinions conveyed by the artifacts produced through the social practice. Public conversations are written and stored, and very often discussions refer to previous posts. In searching for information on a particular topic related to the FOSS world, it is common to enter directly these conversations going through the threads of messages archived in forums or mailing lists. The following quote from the study by Hemetsberger and Reinhardt (2006) makes this process clear:

"Our findings show that newcomers engage in exploring those archives in search of answers to their technical problems. They find the discussions in chronological order, which helps them to re-experience the

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(2001).

[7] As Kuran (1989, 1995) shows in his studies of revolutions, dissonance can also remain latent in many individuals. In this case, a relatively insignificant trigger event, such as a small number of individuals questioning the status quo and showing "inactive" individuals experiencing accumulated dissonance that disagreement is more widespread than expected, can result in what he calls a revolution (Kuran, 1989, 1995, 1998).

lines of thoughts of the discussants. Quite often it is not the content of the discourse but the lines of arguments that provide the most valuable insights for learners." (Hemetsberger and Reinhardt, 2006, p. 208)

Stored conversations are therefore the basic material upon which the FOSS discourse is realized. In debates and conversations, the participants' systems of meanings and values are clarified when community members are pushed to express an opinion on the topic of discussion. In the case of FOSS, an example of this clarifying process is provided by Elliott and Scacchi (2003). The authors report a debate between conflicting views on the use of free software. Two quotes from that debate can give the reader a clearer idea of the capability of the online conversation to capture the emotional level of the discussion and the difference in the systems of values of the discussants:

<CyrilB> neilt: you are compromising our freedom by using non-free software: we can't modify and/or redistribute the source vector file.[…]

<neilt> otoh i see no reason to avoid non-free software either if this is really a freedom thing then we should be free to use whatever we want in which every participant tries expresses her or his opinions and elaborates on them to convince the other to act in a certain way" (Elliott and Scacchi, 2003, p. 26)

Exposed to such a conversation, observers can sense the challenge to form their own opinion on the basis of their own preferences and on the other material conveyed to them by the debate.[8] For example, a FOSS user entering the archives of the community communication just to find a needed piece of information will inevitably be exposed to the electronic communication of the core members, to their set of visions of the world or of the product, opinions and arguments. When exposed to such a debate, the user will suddenly feel compelled to answer questions and to take a position about topics that he or she had never considered. The discourse conveyed by the debate and stored in the community mailing lists interfaces with an individual's systems of experience, opinions, meanings, and representations. The negotiation of meanings that arises from this encounter precisely parallels the engagement with artifacts described above. This process of emerging standards also occurs at the periphery. As a result of this process, standards can be widely dispersed and

[8] This mechanism can be better understood considering a similar (even if more emotional) process described by Victor Hugo in *Les Misérables*: "We may remain more or less open-minded on the subject of the death penalty, indisposed to commit ourselves, so long as we have not seen a guillotine with our own eyes. But to do so is to be so shaken that we are obliged to take our stand for or against", *Les Misérables* (1862), Trans. by Norman Denny, Penguin Books, (1976), p. 32.

shared, and even members of the peripheral "unknown workforce" (Agerfalk and Fitzgerald, 2008) can enter the center of the action and contribute to the productive division of innovative labor within the core. Hence, we propose the following proposition:

Proposition 4: The open access to non-material artifacts exposes peripheral developers to the standards of excellence inscribed in the artifacts and, thus, enables the productive division of labor between the core and the periphery.

In sum, the standards that define work in terms of ambition and quality in the social practice of FOSS are inscribed in non-material artifacts such as code or communication archives. The artifacts communicate standards to new participants as they begin to engage in peripheral activities. When a peripheral member acts on the artifacts, the established standards re-emerge through a negotiation of meanings that is similar to the one described by Wenger (1998b), but in this case, in the relationship between peripheral individuals and the artifacts. When such a negotiation is engaging a substantial number of individuals who then join a community as members of the periphery and enter into a productive division of labor, then they become part of a social practice without necessarily sharing the identical work, but complementing the core in ways that are typical of their nature and difficult for the core to perform.

4 Conclusion and implications

This paper defined the properties of the periphery of communities of creation (dissipation, invisibility and atomization) using the specific context of FOSS and uncovered the different functions the periphery can perform on the basis of those properties (providing a pool for new resources, providing frequent small contributions and occasional ad hoc solutions, and monitoring behavioral adherence to community rules). The energy in time, effort, and passion that peripheral and core contributors devote to online communities contribute to their growth and to an impressive level of output of products and services. Due to a lack of contracts, these resources flow into and out of online communities, and little is known about how to best manage this process (Faraj et al., 2011). The core and the periphery of online communities of creation, such as FOSS communities, usually do not interact face-to-face and divide labor in complex ways. After defining the functions of the periphery, we characterized the community's work as a social practice and theorized how individuals come to share the social practice and join in a division of labor with the core of the community.

This point can be better grasped by considering the analogy echoed in our title in which the FOSS project

development is conceived as a theater play. The periphery and the core, and the theater audience and the stage actors interrelate in a similar manner. First, the periphery and the core share a division of labor, and so do the audience with the actors. The core undertakes the majority of the action, and so do the actors on stage. At the same time, the periphery contributes many small tasks and makes the structure of the code more solid. In a theater, the audience participates by signaling its appreciation or discontent, laughing and possibly crying, and in this way, they contribute to the general atmosphere in the theater, rendering palpable the feelings the play conveys. Second, the stage is the center of the action, the place where the light is. The core and the actors occupy this space for the majority of the time but, sometimes, peripheral members provide important ad hoc solutions, just as someone from the audience can have a role in the play when called up onstage by the actors. Entering the center of the action means becoming visible and attracting attention.

The analogy is interesting because it also allows us to highlight the lack of commonalities between the two settings. Even when invited onstage, a member of the audience can rarely add something meaningful to the play, and most of the time, they are directed by the actors. Conversely, members of the periphery do not need to be invited, but instead they can act and express their ideas without any guidance or endorsement, and most of all, they can actually contribute something significant and path-breaking when their moment comes. This difference is because the members of the audience do not master the social practice of the play and its standards, whereas peripheral members do so with respect to the social practice of the FOSS project. Understanding what drives a social practice may allow peripheral members to be heard even when appearing from seemingly out of nowhere into the center of the action. Moreover, standards also evolve in the course of these events, so peripheral members in these special circumstances also contribute and co-create the social practice. This capability of the FOSS periphery is made possible by the presence of the non-material artifacts, clearly not present in the case of the theater play, that propagate the social practice and its standards. Outside users and developers engage in community discussions based on a casual interest that exposes them to the standards of the social practice and may socialize them to a community they can relate to. The propagation of standards engages outsiders in negotiations of meaning that drive them to become members of the periphery. These peripheral members are atomized and retain idiosyncratic views on the community and its technological agenda and, crucially, they decide to change to the technology if they perceive it as a constraint (Franke and von Hippel, 2003; Leonardi, 2011). This dynamic engagement fuels

the community with new ideas, energies, and the developing capacity that allows for its dynamic growth.

The observations set forth above have implications for organization theory and innovation research. Internal dynamics in online communities of creation are not well understood. Theory that explains how resources enter and leave online communities (Faraj et al., 2011), how authority plays out in online communities (Dahlander and O'Mahony, 2011), how online communities relate to firms (Colombo et al., 2012), and how firms can collaborate with online communities in fruitful ways (Jarvenpaa and Majchrzak, 2010; von Krogh and Haefliger, 2010) is still in its infancy. The practice lens adopted here joins recent work in theorizing organizational dynamics (Feldman and Orlikowski, 2011) with respect to the enactment of organizational reality in daily work, which holds important implications for theorizing technology in use and as an agent of change in organizations. Our discussion of non-material artifacts (Callon, 1991; Faulkner and Runde, 2010) as agents of community growth and diversity builds on recent work that takes the material context of work as a significant factor for technology development and organization (Leonardi, 2011). Due to the absence of face-to-face contact, the propagation of standards from the core to the periphery occurs through non-material artifacts only. The capacity of non-material artifacts to communicate the standards of a social practice allows us to conceptualize how the division of labor can be established in a shared social practice within a community of creation. Future work may attempt to gauge the role of artifacts in other intra- or inter-organizational dynamics of online communities.

Online communities of creation have received considerable attention in innovation studies due to their impressive record of creating novel technologies as well as pioneering an innovation model that blends private and collective aspects (von Hippel and von Krogh, 2003). The survival and growth of online communities is little understood, and we contribute to a more fine-grained understanding of how new members enter a community and find a productive role in its periphery. The study of user communities, more generally, may benefit from further research into the dynamics and mobility of members within communities (see also von Hippel, 2005; Franke and Shah, 2003) and their relevance to businesses and firms that interact with the communities (Hienerth et al., 2011).

Further, a number of implications for policy and management practice are relevant here. Non-material artifacts pervade everyday life in today's global society. Documents, images, videos, and music that are distributed over the internet are readily available and accessible to millions of people. Personal documents,

such as airline tickets, residence permits, passport information, and grading sheets, are also non-material and remain relevant in many areas of private and public life. The interpretation of the value and meaning of these artifacts occurs in more and more diverse settings and impacts individuals' roles in organizations, in governments, and in relationship to peers and fellow citizens. We suggest that non-material artifacts carry with them the standards elaborated by a social practice, and they impart these standards to anyone who uses or works with them. With the expanding reach of non-material artifacts, the actors in government and business organizations need to pay closer attention to the values and standards they inscribe in artifacts and how and to what extent the standards reflect and represent their social practice. Highly diverse constituents and clients thus represent both a source of uncertainty as well as a potential source of support and outreach.

For governments as well as for business, online communities are becoming more and more relevant as a space of communicative and creative action. New policies geared toward online citizenship, electronic tax returns, electronic voting, and many other government transactions, have become reality as part of e-government (Warkentin et al., 2002; Layne and Lee, 2001; Moon, 2002). The appreciation of non-material artifacts as carriers of standards of excellence may bring higher awareness of political processes that produce these artifacts and of the engagement with the artifacts in peripheral parts of the communities affected and involved in the transactions, including the citizens of a nation or a group of individuals living on the same street.

In business, sourcing ideas from customers and users has a long-standing tradition, and its relevance has grown and keeps growing with internet literacy and the access to online resources by consumers and users of virtually all ages and levels of competency (von Hippel, 1988; Füller et al., 2008; Hienerth et al., 2011). The possibilities of spreading personalized, non-material artifacts pertaining to products as marketing tools (Aral and Walker, forthcoming) generate a set of questions in marketing about the creation of new stages for expression and creative contributions by potential customers and with products that offer interactivity with other customers, who may also have a similar desire for shared creative expression. Questions about how communities form and what their central content and values should be becomes a question for designers both of products but also of content that can use or appropriate marketing strategies, subvert them, or generate advocacy about and around the social practices that underlie or should underlie a business. These issues seem to be more about the role of non-material artifacts than anything else.

Further, customers and users may contribute to innovation projects of firms and share their insights (Harhoff et al., 2003) through interactions in communities that involve both firms and customers in scenarios in which firms that host consumer communities resemble the core and periphery structures described here (Jeppesen and Frederiksen, 2006; Shah, 2006). In this case, joint work on innovation projects may turn any online community into a community of creation. The understanding of how standards of excellence propagate serves as a fundamental element by which to establish and maintain a "stage" for heterogeneous members of a periphery to contribute creatively. In this respect, our analogy of the theater can serve to underscore the importance of these strategies and to provide a sense of how a core should conceptualize a periphery in order to mobilize its full potential. In some representations of the play *Tonight We Improvise* (Pirandello, 1930), the boundary between the actors and the public (the "fourth wall") falls when the actors enter the audience and interact directly with them. This practice is sometimes used in meta-theatrical performances that are aimed at creating a bond between the audience and the actors. The points of view of the public (the periphery) and those of the actors (the core) become interwoven, thus enhancing the actor's awareness of the theater's general atmosphere and intensifying the audience's reception of the emotions and message of the play. This paper has demonstrated the integral role of the periphery in online creative communities such as FOSS, and hopefully it has communicated the value of caring about the periphery, respecting its role and the importance of not trying to "drag its members to the core," while giving them the needed space for expression and allowing them to realize their function as best they can. Allowing the periphery (audience) to interact with the core (actors) has the potential for tremendous success, as Pirandello's Nobel Prize suggests.

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