Re-use and Patterns of Digital Innovation in Open Crowds: Linking Empirical and Computational Approaches

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Organizations increasingly use crowds to create digital innovations, novel and useful software-based products or services (Yoo, Henfridsson, & Lyytinen, 2010). They invite a diverse crowd of individuals to solve an innovation problem in a virtual design contest, in which the crowd competes for the best performance (Boudreau, Lacetera, & Lakhani, 2011; Gulley, 2001; Hildebrand, Häubl, Herrmann, & Landwehr, 2013). Participating in a design contest for digital innovations requires developers to search for a novel solution along (at least) two fundamental design dimensions: the *user-facing functionality* set or features (i.e., what can the user "do" with this new digital 'app' and how is it presented?), and the underlying *technology* (the code), the technological solution that affords this user functionality set (i.e. how is this set realized by code?). Thus, in order to win the contest, developers need to create designs that are both useful and usable, and score well in both dimensions.

Recently, organizations implement virtual contests for digital innovations in an increasingly transparent way, following the logic of 'open source' (Levine & Prietula, 2014). They provide participants with access to information about others' submissions throughout the competitive and multi-staged process, and encourage several iterations of reuse instead of independent and parallel development efforts (Brunswicker, Jensen, Hsiang, & Song, 2016; Wooten & Ulrich, 2015). In short, they foster truly open crowds, in which participants freely share, reuse and remix their digital applications. We define reuse as the process by locating and using knowledge freely shared by others (Alavi & Leidner, 2001; Majchrzak, Cooper, & Neece, 2004).

In such virtual design contests, this process is transparent if it provides access to two kinds of social information that are absent in non-transparent contests: (1) information about other design implementations (the actual code and feature) and (2) information about the quality of other solutions (the score). In essence, this transparency shapes how each developer searches for better performing designs across the collectively evolving design space. In this paper, we focus on the reuse process in open and transparent crowds that aggregates 'bottom-up' from the heterogeneous individual reuse behaviors (Newell, 1990).

Existing work already suggests that transparency moderates the collective design behavior in open crowds. While some authors argue that transparency leads to convergence towards the best performing design (Bayus, 2013; Boudreau & Lakhani, 2015), do other studies suggest that transparency can also trigger discontinuities, even among those at the top that are aware of their greater chances of winning the contest (Brunswicker et al., 2016; Ren, Nickerson, Mason, Sakamoto, & Graber, 2014; Sakamoto, Tanaka, Yu, & Nickerson, 2011). Indeed, literature suggests that reuse patterns are complex and non-linear. One of the reasons for that is that individuals change their reuse strategy in response to transparency (Brunswicker

et al., 2016; Gulley, 2001). Transparency directly moderates this risk preference of the developers because it reveals the relative quality of one's submission. Such information triggers comparison processes among the competitors, which may trigger a developer to engage in riskier reuse of designs of much higher quality (Boyle & Shapira, 2012; March & Shapira, 1992; Michinov, Jamet, Métayer, & Le Hénaff, 2015). Such explorative reuse is risky because developers are not familiar with the design, its code and its features. Thus, if there is no need to take risk, developers may opt for a less risky reuse choice. They search and adopt solutions more similar to the own one (Kyriakou, Sabnis, & Nickerson, 2017; Majchrzak et al., 2004). In essence, transparency may trigger variability in terms of risk preferences throughout an iterative virtual contest. However, the choice of a certain reuse behavior is not only a question of risk preference. Developers may also have a strategic preferences for one or the other aspect of the design task (Hildebrand et al., 2013): While some developers may focus their efforts on improving the quality of the code, other's may focus their efforts on the user functionality (and its quality). However, such a functionality centered reuse preferences sometimes comes at the price of the quality of the code. Thus, reuse in transparent crowds may cause unique reuse and performance patterns as the participants may not focus their attention in a one-dimensional way.

In order to unpack how such micro-level variability in reuse choices unfolds at the collective level, this paper asks two simple research question: *How does transparency shape the performance patterns of reuse in open crowds for digital innovation?* We answer this question using an agent-based simulation model. This model extends the theory of variable risk preferences (Boyle & Shapira, 2012; March & Shapira, 1992) to represent the behavioral rules of individual agents. It accounts for the fact that in context of open crowds, developers design and reuse digital innovations along two dimensions: code (usable) and feature (useful).

Our results reveal unexpected discontinuous performance patterns. Design preferences, a bias on either code or feature, lowers the collective performance of the crowd. However, transparency insulates those at the top, the leaders of the competition, from such negative effects. It produces high performing designs even if developers focus their efforts more on code or feature. Further, while transparency reduces variability and smooths the patterns among those at the top, it also creates unique opportunities for 'newcomers' to submit high-quality applications.

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