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The complementarity of openness: How MakerBot leveraged Thingiverse in 3D printing

Joel West [a,*], George Kuk [b]

[a] KGI — Keck Graduate Institute, United States
[b] Nottingham Business School, United Kingdom

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ABSTRACT

Selective openness allows a firm to sell a systemic innovation that combines both open and proprietary technologies. Such firm strategies are now common for open source software and other information goods. However, they pose conceptual and practical uncertainties for hardware-focused companies, particularly as research on open hardware has emphasized community rather than firm success. Here we study firm openness in 3D printing, with a case study of how MakerBot Industries leveraged external communities and selective openness become the consumer market leader. After reviewing the literature on systemic innovation and selective openness, we document the proprietary strategies of a dozen startup companies during the first two decades of the 3D printing industry. We contrast this to the open hardware, software and content strategy that MakerBot's founders used to enter and grow the consumer market from 2009 onward. We show how MakerBot shifted to a selectively open, systemic innovation strategy that complemented proprietary hardware and software with open user-generated content from its Thingiverse online community. From this, we suggest the inherent complementarity of selective openness strategies between open and proprietary components, and conclude with predictions as to when and how a startup or incumbent firm will combine open and proprietary elements.

1. Introduction

For decades, the incentives to create and diffuse innovations have been associated with the strength of appropriability regimes and the ability of a private inventor to appropriate private returns from their economic investment. Traditionally such incentives are subject to strong IP protection mechanisms such as patents, copyright and trade secrets (Nordhaus, 1969; Teece, 1986).

Over the past decade, some previously proprietary incumbent firms have experimented with opening parts of their complex offerings to win cooperation from adopters, complementors and even rivals (West, 2003; Henkel, 2006; Shah, 2006; West and Gallagher, 2006; West and O'Mahony, 2008; Spaeth et al., 2010; Henkel et al., 2014). The availability of shared IP from an open source community has also enabled the formation and entry of new firms that build upon these collective efforts (Gruber and Henkel, 2006; Dahlander, 2007).

Prior studies have emphasized openness in software, endowed with the characteristics of information good. Therefore, we would expect the findings in software to representative of the larger class of information goods, which are nonrivalrous in consumption and have little or no marginal cost, making them nearly costless to disseminate (cf. Varian, 1998; Kogut and Metiu, 2001; Cusumano, 2004; Von Hippel and von Krogh, 2003). However, limited research on open hardware communities has suggested that their economics and organization are quite different (e.g., Raasch et al., 2009), and thus a goal of this paper is to extend our understanding of these communities to explain how firm strategies leverage these communities.

Here we examine how openness influenced the success of 3D printers, an industrial technology from the 1980s that faced slow adoption until the RepRap open hardware project stimulated the subsequent entry of consumer-focused startup producers. We focus on the case of MakerBot Industries, the leading maker of consumer 3D printers, with its unique value creation strategy. The firm was founded based on an open source hardware and software strategy — complemented by its Thingiverse open content community — and kept its user-generated content open even after it switched to proprietary hardware and software (See Fig. 1).

From this, we extend the research on selective openness from software to hardware business models. Specifically, we propose an extension of the open source model to suggest a more general pattern of what we term the *complementarity of openness*. In such cases, openness increases the value of the non-open part of a firm's value proposition, and thus a firm can only be open if it has something that is closed which allows it to generate revenues and profits to support the business. We also highlight the unique selective openness constraints of new firms, that leverage open technologies to create value and enter markets while seeking proprietary imitation barriers to protect value capture. We offer specific predictions as to how resource limits will influence a new firm's openness strategies, and also suggest which parts of a complex offering will be selectively opened (or closed).

* Corresponding author.
E-mail addresses: kgi@joelwest.org (J. West), George.Kuk@nottingham.ac.uk (G. Kuk).

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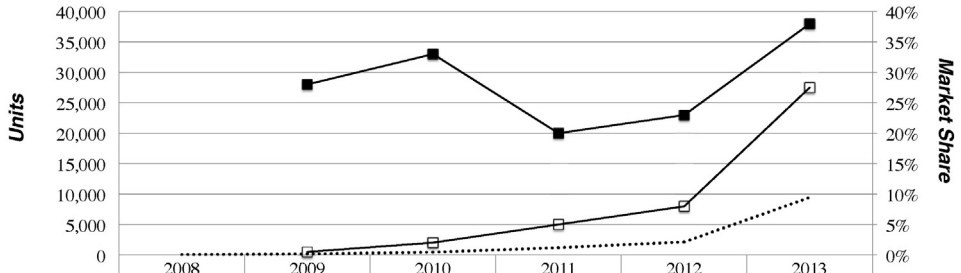

	2008	2009	2010	2011	2012	2013
Thingiverse New Objects	31	159	453	1,181	2,127	9,436
MakerBot Printers (Unit Sales)		500	2,000	5,000	8,000	27,500
MakerBot Printers (Market Share)		28%	33%	20%	23%	38%

Fig. 1. MakerBot and Thingiverse success.

The paper begins by reviewing the relevant theoretical literature, and then summarizes the technical and market context of late 20th century industrial 3D printing that enabled a rash of consumer-focused startups in the early 21st century. We review the evolution of the MakerBot product and content strategies, and from this suggest testable propositions, other theoretical implications and opportunities for future research.

2. Open strategies for systems, communities

The value proposition for consumer 3D printing requires two complementary offerings: systems and content. Consumer value is realized when digital designs are transformed into physical objects using a system that includes graphics software, a computer and a 3D printer. Content means the creation, modification and sharing of these digital representations of tangible objects — often shared through online communities. Digital designs are complementary goods that make the adoption of 3D printing systems more valuable.

Here we review research on the role of complementary goods in systems adoption, with a focus on community-sourced complements. We also consider how firms interact with external communities, and selectively provide outbound openness (and accept inbound openness) to advance firm goals, particularly in the context of open source software and hardware.

2.1. Complementary goods and systems adoption

Innovations are adopted based on their characteristics, and also the characteristics of their adopters. In particular, earlier adopters (such as hobbyists or other enthusiasts) are more eager to try new technologies without proven benefits and are tolerant of usage difficulties (Rogers, 1995). For many products, the value of the innovation depends on the provision of certain complementary goods that make the innovation more valuable (Teece, 1986).

The creation and adoption of a technological system is different from other kinds of innovation, in that the value received by the adopter depends on the value of the overall system. Promoters of such systems innovation face the challenge in combining and coordinating the production and adoption of different components of the system by external actors (Maula et al., 2006). Although systems innovators can attract a variety of complements, it is difficult to align external actors and processes. In relation to open innovation, systematic innovation entails boundary management (Jarvenpaa and Lang, 2011; Teigland et al., 2014) within and across the borders of firms. Open innovation research only partially explains how firms may combine open and proprietary components that are subject to different licensing regimes (West, 2006).

A particular type of systems innovation is a platform, which has two key attributes. The platform provides well-defined interfaces that enable third parties to provide complementary goods (such as "apps") for the platform, and the platform sponsor nurtures an ecosystem of firms (or individuals) who supply such complements (Bresnahan and Greenstein, 1999; Gawer, 2009). Sponsors selectively provide openness — in some parts of their technology but not others — to attract both adopters and a supply of complements while retaining enough proprietary control to extract profits from the platform (West, 2003; Boudreau, 2010; Eisenmann et al., 2011).

External user communities have been increasingly important to firms in industries organized around digital goods. Firms can tap external communities as part of an open innovation strategy (Spaeth et al., 2010; West, 2014). Such communities provide a source of complementary goods, particularly for information goods such as online information (Nov, 2007), musical sounds (Jeppesen and Frederiksen, 2006) and video games (Jeppesen and Molin, 2003). Online communities can also provide support (Lakhani and von Hippel, 2003), bug reports (Dahlander and Magnusson, 2008) and marketing feedback (Schau et al., 2009). For would-be entrepreneurs, the firm-sponsored communities of today's "app economy" provide an opportunity to develop and diffuse new add-on products (MacMillan et al., 2009).

2.2. Selective openness

Firms often choose to be selectively open in dealing with external actors (Alexy et al., 2013). Because too much revealing may erode competitive advantage and enable competitors, they open part of their overall offering (such as a module within a complex system) or provide partial openness for a broader part of that offering (West, 2003). They freely reveal information that could also induce potential rivals to follow a similar openness strategy, particularly for information that is less strategically important (Henkel, 2006; Henkel et al., 2014). At the same time, their willingness to be open may be limited by their ability to appropriate value from the non-open parts (West, 2006).

Over the past 15 years, most of the experimentation in (and research on) firm openness has focused on open source software. Firms have worked with and created external online communities that create free and open source software (Lakhani and von Hippel, 2003; Shah, 2006; Dahlander and Magnusson, 2008). Such communities are characterized by a standard form of IP license, a form of cooperative production and a mechanism of governance (West and O'Mahony, 2008). The license allocates rights to use and modify IP for community members and non-members alike (Perens, 1999).

For systems adoption, these communities can provide the core functionality of a system, enabling firms to sell higher-value proprietary complements. Conversely, firms may choose to offer a proprietary platform and seek open source donations of complements (West and

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