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DOES IT PAY TO BE OPEN?

CORPORATE KNOWLEDGE DEVELOPMENT,

COMMUNITY-BASED INNOVATION & VALUE CREATION

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Does it Pay to be Open?
Corporate Knowledge Development, Community-Based Innovation & Value Creation

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Firms are increasingly contributing knowledge to the open and collaborative product development organizations known as user innovation communities. This behavior is perplexing in light of traditional theory in strategy and innovation management, which emphasizes protecting knowledge in order to sustain competitive advantage. As a result, explanations for why firms contribute knowledge to innovation communities have focused on indirect sources of value generation, such as the introduction of complementary products and services, displacing competitors in the value chain, and standard setting. However, another powerful source of value generation exists: the ability to co-develop knowledge that will subsequently be used in commercial products. We build a theoretical basis for this possibility: by drawing on recent work in the area of user and community-based innovation we explain why insights from innovative users can generate value for firms. We test our hypotheses on a novel data set that captures the stock market response to open source code contributions made by public, U.S.-based, software firms over a thirteen-year period. We find that knowledge contributions generate pecuniary value for firms. We also find that contributions of more novel knowledge generate greater value for firms than contributions of updated or existing knowledge. Finally, we find that contributions of novel knowledge intended for products aimed at generalist consumers rather than experts generate even greater returns.

Keywords: Innovation, knowledge, product development, user and community-based innovation, open source software

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INTRODUCTION

Open source software is an exemplar of a fundamentally different organizational model for innovation and product development—referred to as collective invention (Allen 1983), private-collective innovation (von Hippel and von Krogh 2003) and community-based innovation (Franke and Shah 2003). Communities provide participants with the social context and resources to create useful and publicly available software. Community-based innovation initiatives are distinctive from proprietary corporate product development projects in that they allow open access to knowledge.

A number of firms now engage with communities. Many such companies are recognized not just for building products based on open source software, but also for contributing knowledge to open source communities. For example, Sun Microsystems contributed over nine million lines of code to the Star Office project (Sun Microsystems 2000), IBM contributed over half a million lines of code to the Apache Software Foundation (IBM 2004), and Novell donated more than 200,000 lines of code to form the basis of Hula, a new community project (Novell 2005). These and similar actions have triggered curiosity within the academic community, with scholars interested in both whether or not contributing knowledge to the commons generates value for firms and the reasons for why it does so (Lerner and Tirole 2005, von Hippel and von Krogh 2003): "Why, then, would innovating firms share technological knowledge with their innovations system?" (Spencer 2003).

Empirical data linking community participation with firm performance are rare. A single existing study provides an initial glimpse at the relationship between participation and performance, finding that increasing levels of technical participation in a community benefit firms to a point, after which benefits decline amongst based on cross-sectional survey data collected from managers of Dutch firms commercializing open source software (Stam 2009). Such firm-level data provide a promising starting point and suggests that further investigation into this phenomenon is warranted. Yet, studies investigating a wider set of firms and understanding why contributions to the commons generate value (i.e., understanding the characteristics of contributions that lead to different levels of value generation) requires analysis at the level of the contribution. We provide such data.

Conflicting theoretical perspectives pertaining to the question of why knowledge contributions might benefit firms exist. On one hand, the literature on user-and community-based innovation posits that contributing knowledge to user communities should generate value for firms (Colombo et al. 2013, Gächter et al. 2010). Knowledge contributions provide a basis for users and firms to collaboratively develop and improve upon ideas. Collaborations with users provide firms with unique insight beneficial to their internal product development efforts that would be difficult or impossible to access through other means (Chatterji and Fabrizio 2012, Riggs and von Hippel 1994, Winston-Smith and Shah 2013). The introduction of innovative products based on these insights should, in turn, generate value for firms.

On the other hand, well-established strategic management theories suggest that knowledge contributions alone should decrease value, unless deployed strategically; that is, knowledge contributions only indirectly enhance a firm's performance. Proponents of the knowledge-based view of the firm argue that because knowledge-based resources can be difficult to imitate and socially complex, heterogeneous knowledge and capabilities are the major determinants of superior performance and sustained competitive advantage for firms (Grant 1996, Kogut and Zander 1992, Spender 1996). However, knowledge contributed to communities is widely accessible, thereby eroding a firm's exclusive access to knowledge. Both the knowledge-based view of the firm and work in the area of appropriability suggest that knowledge contributions made to communities will decrease firm value, unless made with strategic intent (Alexy et al. 2012, Goldman and Gabriel 2005, Hardy 2013, Spencer 2003, Waguespack and Fleming 2009). Several studies note the potential strategic benefits that firms can gain by contributing to innovation communities (Capra et al. 2011, Dahlander et al. 2008, Haefliger et al. 2011, Henkel 2009). Empirical research is needed to assess whether or not knowledge contributions might *directly* benefit firms, or whether benefits must be derived indirectly.

We examine the relationship between open source contributions and firm performance. We investigate whether or not contributing knowledge to innovation communities generates or diminishes value for firms, and whether or not firms benefit by co-developing knowledge with users: *do firms reap financial benefit from contributing knowledge to user innovation communities? Do differences in the* *knowledge a firm contributes affect the value of the benefits generated?* And, *does the nature of the target market moderate the value generated by contributions of novel knowledge?* We build on existing empirical insights from the user and community-based innovation literature to construct a theoretical framework that explains *why* contributing knowledge to user innovation communities generates value for firms and that begins to delineate the *types of tasks* for which leveraging communities might be most beneficial.

We test our theoretical predictions by examining stock market responses to contributions of open source software code using an event study model (Austin 1993, MacKinlay 1997). This approach has been used in the marketing and strategy literatures to estimate the value generated by a variety of innovation-related activities (Chaney et al. 1991, Fosfuri and Giarratana 2009, Koku et al. 1997, Sood and Tellis 2009, Srinivasan et al. 2009). Our novel dataset is built around the press releases of all firms listed on U.S. stock exchanges over a thirteen year-period.

Three key findings are uncovered. First, contributions to the commons generate value for firms. Second, contributions of more novel knowledge generate greater value for firms. Third, the nature of the target market moderates the value generated by contributions of novel knowledge. Overall, our findings suggest that firms derive value by engaging user communities in the co-development of knowledge.

LITERATURE REVIEW & HYPOTHESES DEVELOPMENT: DO CONTRIBUTIONS TO USER COMMUNITIES GENERATE VALUE FOR FIRMS?

Innovation is a complex, challenging, and knowledge-intensive activity (Brown and Eisenhardt 1995, Clark and Fujimoto 1991, Taylor 2010). Firms often have difficulty in generating the knowledge necessary to innovate internally (Chesbrough 2003, Henderson 1993, Tushman and Anderson 1986) and the success rate of corporate product development projects is low (Cooper and Kleinschmidt 1986, Taylor 2010). Therefore, many established firms look to acquire and exploit knowledge developed externally (Arora and Gambardella 1990, Chesbrough 2003, Cohen and Levinthal 1990, Helfat 1997). Empirical findings from across the innovation management literature suggest that accessing and integrating knowledge from a product's potential consumers is one way in which firms can improve their chances of product development success (Cooper and Kleinschmidt 1986, Griffin and Hauser 1993). The user innovation literature goes one step further, arguing that because the majority of potential consumers do not necessarily recognize or have unmet product needs, market research that relies on information collected from the "average" consumer will not uncover insights that lead to the development of revolutionary new products. Instead, this literature suggests focusing on a small fraction of innovative individuals—user innovators—who experience needs unfulfilled by existing products and services and therefore create innovative prototypes that fulfill those needs (von Hippel 1988). Below, we construct a theoretical framework for understanding how firms might generate value from working with users based on observations and empirical findings from the user and community-based innovation and strategy literatures.

Can Firms Generate & Appropriate Value from User Generated Knowledge?

Profiting from innovation requires both generating and appropriating value (Teece 1986), and to date the literature has not examined whether or not firms are able to do so through their interactions with innovative users and their communities. Below, we explain why firms can gain unique knowledge by collaborating with users—knowledge that is difficult or impossible to access through other means and is therefore a valuable input into a firm's product development process—and why that knowledge may be fully or partially appropriable even without protections provided by legal intellectual property mechanisms or secrecy.

User Innovators as a Source of Valuable Knowledge

Users are distinguished from other sources of innovation by the primary motive that fuels their innovation activity: users innovate because they expect to derive benefit by *using* the innovations they create (Kline and Pinch 1996, von Hippel 1988). In contrast, many firms innovate because they expect to derive pecuniary benefits by selling the innovation to others (Chandler Jr 1990, Schumpeter 1942, von Hippel 1988). And, many academics innovate because they expect to derive status and reputation-enhancing benefits by publishing and promoting their results (e.g. Merton 1979). These differences in motives produce differences in the process by which users, as compared to employees of firms and academic scientists, develop their innovations.

Three unique characteristics of the user innovation process—identification of unrecognized needs, immersion in the problem context, and community-based problem solving—allow users to expose qualitatively different insights than those exposed by other sources of innovation (Riggs and von Hippel 1994, von Hippel 1988, Winston-Smith and Shah 2013). These insights can be used as an input to the corporate innovation process.

Users Conceive of New Needs. Users experience a variety of needs left unfulfilled by existing products (von Hippel 1988). They utilize this knowledge to identify the problems for which they will find innovative solutions. Non-users may not be able to recognize these needs as quickly or at all. As a result, user innovations are more likely to embody altogether new product functionality than innovations made by firms (in contrast, innovations made by firms tended to improve existing product functions along dimensions known to be important to customers) (Riggs and von Hippel 1994). By working with innovative users, firms will gain valuable insights into previously unrecognized needs and their significance to consumers that they cannot gain from other sources. Hence, firms may be able to introduce radical or altogether novel products or features by working with users.

Users Immerse Themselves in the Problem Context. Different users may use a product in different ways or in different environmental conditions. Because individual users are situated in the environment in which an innovation will be used, they are often able to build a deep and accurate understanding of the environment. This is important because environmental factors often affect the functioning of an innovation in unexpected ways (Tyre and von Hippel 1997). User innovators utilize this knowledge as they troubleshoot and correct problems with existing products, and as they design and construct new innovations (Ogawa 1998). In contrast, non-users' (*e.g.,* R&D employees, academic innovators) perceptions of the circumstances under which the product will be utilized can diverge from the realities of actual use. Such mismatches can result in the failure of products designed by non-users. However, knowledge pertaining to the problem context can be costly to acquire, transfer, and use in a new location, making it difficult for non-users to correct a product's shortcomings (Ogawa 1998, von Hippel

1994). Understanding the nuances of the environments in which a product is used would enable a firm to design a more effective product. By working with innovative users, firms will gain a more nuanced understanding of the context(s) in which a product is utilized and be able to incorporate this knowledge into their innovation process. Knowledge sourced from innovative users is therefore likely to provide valuable insights to firms, enabling them to develop more robust products.

Users Gain Solution Knowledge from Innovation Communities. By working within communities, users are able to tap a pool of heterogeneous knowledge and bring that knowledge to bear on a particular problem (Brown and Duguid 2001, Franke and Shah 2003, Wenger 1998). Increasing the variety and diversity of solutions considered leads to the creation of products that are more innovative (March 1991). Bringing together individuals from *outside* the core discipline of a given field improves the chances of solving a problem and often results in the creation of highly innovative solutions because outsiders frame problems differently (Guimerà et al. 2005, Tapscott and Williams 2006). Interacting with a large number of individuals who possess distinct knowledge bases allows users to generate effective—and sometimes even ingenious—solutions to their problems. By working with innovative users, firms gain valuable insights that broaden their knowledge base in unexpected directions, expand the solution spaces they consider, and gauge the potential for consumer interest in the innovation needs. Knowledge sourced from innovative users is therefore likely to provide valuable insights to firms.

These three characteristics of the user innovation process allow users to expose qualitatively different insights from those exposed by other sources of innovation. Specifically, possessing user knowledge will allow firms to create innovations that are more likely to address altogether novel needs, embody a deep and nuanced understanding of the environmental context in which the innovation must function, and draw upon a more heterogeneous base of solution knowledge. These insights can be used to inform a firm's technological- and market-related decisions. We therefore expect that firms will generate value by using this knowledge to fuel their R&D process.

Two empirical studies support these arguments. Both studies show how user knowledge can benefit firms' product development efforts in the context of the medical device industry. Firms working *jointly* with innovative users create patents that are cited more often, contribute to a broader set of follow-on technologies, and occur earlier in the product life cycle than when firms innovate independently (Chatterji and Fabrizio 2012), suggesting that firms can create technologies that are more important—and create those technologies earlier—by working with users. Firms engaging in external searches for innovative product ideas are more likely to incorporate innovative insights from innovative users than from academic or commercial sources into both their patents and radical products (Winston-Smith and Shah 2013), suggesting that user-generated insights are not only valuable inputs in the product development process, but also more useful than insights from other sources of innovation. Overall, firms can learn a great deal from innovative users—and these insights can lead to the introduction of more novel, cutting-edge, and important products and features.

Appropriating User Knowledge

Deriving benefit from user-generated insights may require that firms actively collaborate with users, because of the nuanced and context-specific nature of user knowledge. User knowledge has been described as both tacit and "sticky": difficult to communicate, based on experience, and easily understood only while working in the context in which a need or problem is encountered (Tyre and von Hippel 1997, von Hippel 1994, von Hippel and Tyre 1995). Such knowledge is difficult to transfer, a characteristic that limits free "spillovers" of user knowledge to firms. Firms desiring access to the valuable insights that users provide may need to engage in collaborative and immersive modes of knowledge transfer; close collaboration improves the likelihood of transferring nuanced and/or tacit knowledge (Uzzi 1996). Participation in innovation communities is one form that collaboration can take. For example, IBM currently employs hundreds of full-time employees to work within various open source development communities such as Linux, Eclipse, and Apache.

In addition, by contributing knowledge and being known within a community, firms may be able to generate more specific user feedback—that is, feedback that may be more useful to the firm than to others. Von Hippel & von Krogh (2003) suggest that "users whose identity is known to the community enjoy greater benefits from revealing their innovations than do those who are less integrated (Calhoun

1988, Taylor 1989, Wenger 1998). This is so because their ideas, bug reports, viewpoints, or code can be reviewed or commented upon by other users, and in terms of learning benefits the group's feedback can be direct and specific." Along similar lines, an open source advocate and former principal architect for Sun Microsystems suggests that fears associated with contributing competitive intellectual property are unwarranted, while the benefits to firms' product development efforts are significant: "Your competitors… don't want your IP because it's worthless, and they are sure of it. So, contributing that new feature that is so important to your business is likely going to create zero buzz at your competitor's HQ, yet still give you the benefits discussed above. In addition, the open source project as a whole will better understand your business, and is likely to find innovative improvements you've never considered" (Falkner 2013).

Based on the theorizing delineated above, we suggest that engaging users provides firms with knowledge that improves their ability to develop innovative new products and thereby generate value; and that because user generated knowledge is sticky and context-specific, those firms that actively engage with users will be able to appropriate benefits from this knowledge. We use these ideas to scaffold our empirical examination of the effects of community participation on a firm's financial performance. We examine the following three questions. First, do firms benefit financially from contributing knowledge to innovation communities? Second, do contributions of novel knowledge generate greater returns than contributions of existing knowledge? And, third, does the nature of the target market moderate the value generated by contributions of novel knowledge? Below, we build additional theory that explicitly links contributions to innovation communities to corporate value generation.

Creating Value by Working with User Communities

Contributions to communities are shared freely and openly. How then, can firms generate value by contributing to a community? The "theory of private-collective innovation" suggests that contributions should be observed when "the costs of free revealing are less than the benefits" (von Hippel and von Krogh 2003). A number of benefits have been suggested that meet this criterion, some of which involve the direct application of knowledge and others of which involve indirect applications of the knowledge. Firms might benefit directly from user-generated knowledge by gaining insights about the needs of users and thereby developing differentiated knowledge base compared to competitors (Goldman and Gabriel 2005) and/or by introducing innovative products faster than the competition (and expecting at least some of these products to be imitated by competitors). Firms might also benefit by the indirect (strategic) use of knowledge to sell complementary services (or products) such as testing, installation, consulting and customization, and support; shaping standards and the actions of institutional actors (Alexy et al. 2012, Goldman and Gabriel 2005, Spencer 2003, Waguespack and Fleming 2009) and/or using open source development to establish the capability to sell products and services complementary to a firm's proprietary offerings, thereby potentially displacing other parties in a value chain and freeing consumer resources (Hardy 2013). For these reasons, we suggest that contributing code to user innovation communities will generate value for firms.

> ***Hypothesis 1: Contributing knowledge to user innovation communities will generate positive stock market returns for firms.***

Contributing Code to Generate User Insights: Contributions of Novel, Updated, or Existing Knowledge Have Different Generative Effects

> *"Of all the business reasons [for tapping into the knowledge of consumers and users by participating in open source software development]… design help may be the most important. Many software products fail because they do not meet the needs of their intended users." (Goldman and Gabriel 2005, p.80).*

In hypothesis 1, we discussed the many ways—through both the direct and indirect use of knowledge—that code contributions might benefit firms. To date, explanations focused on benefits derived through the indirect use of knowledge have been favored, as theory assumes that the knowledge contributions are "lost" to the firm as a direct basis for competitive advantage (Grant 1996, Teece 1986). As a result, little attention has been paid to the possibility that contributed knowledge can become a platform upon which novel insights are built. We suggest that code contributions can benefit firms by serving as a platform to harness knowledge from innovative users.

If firms are benefiting from contributing code by gaining user insights, we should see differences in the benefits derived from contributions of new, updated, and existing knowledge. It is important to note that such a pattern would most likely hold only if firms were directly benefitting from knowledge insights provided by users (*i.e.*, if firms were gaining insights about the needs of users and thereby developing differentiated knowledge base compared to competitors and/or introducing innovative products faster than the competition). We would *not* expect to see differential levels of value creation from contributions of novel, updated, and existing knowledge if firms were deriving benefit solely through the indirect (strategic) uses of knowledge: in such cases, the core factor is the release of proprietary knowledge into the open domain, and whether that knowledge is new, updated, or existing should be largely irrelevant.

We now turn to explaining why contributions of *novel knowledge* should be more generative—and therefore create more value for firms—than contributions of updated or existing knowledge. User communities provide their participants with valuable feedback and development assistance (Franke and Shah 2003). Such assistance is likely to be more beneficial to firms interested in developing knowledge that underpins new products, rather than refining or supporting existing products. Early versions and prototypes of new products often have significant room for improvement (Goldman and Gabriel 2005, Moore 1991, Raymond 1999). Firms often face challenges in understanding the needs of potential consumers, as well as in developing the solution-related information underlying a technology (Alexander 1964, Chesbrough 2003, Cooper and Kleinschmidt 1986). Users, as described earlier, can provide knowledge on both issues, resulting in the development and refinement of a product's functionality. For example, when software code is contributed to gather insights regarding desired functionality, a firm might alter the features and functionality of a subsequent product offering such that the refined product is far superior to the product that might have been released without insights from the open source community (Goldman and Gabriel 2005, p.86-87). Garnering such insights from a user community can help prevent subsequent product failure in commercial market (Raymond 1999)—and is therefore very valuable for firms. For these reasons, contributing novel knowledge to a user innovation community should increase a firm's likelihood of introducing a successful product.

While firms may gain some innovative insights through the contribution of *updates*, the innovative benefits gained from such releases are likely to be less than the innovative benefits garnered from the release of novel knowledge (Chaney et al. 1991). Thus, contributing updates to knowledge that has already been released in proprietary or open source form is likely to provide the firm with limited innovation-related benefits as compared to contributions of novel knowledge.

Finally, firms may also contribute *existing knowledge* pertaining to commercially-available products. The firm is likely to have received ample feedback from consumers on such products; hence contributions to innovation communities are unlikely to result in valuable feedback. Perhaps not surprisingly then, such contributions are often made for reasons related to cost reduction, rather than innovation (Bonaccorsi et al. 2006, Dahlander and Magnusson 2005, Goldman and Gabriel 2005). For example, firms might contribute code for unprofitable or discontinued products, thereby releasing themselves from support and maintenance costs (Goldman and Gabriel 2005).[3] Firms might also contribute knowledge pertaining to discontinued product development projects in order to motivate (or not demotivate, as the case may be) valued employees who invested significant effort and time into the project (Goldman and Gabriel 2005, p.85). Such contributions signal the termination of a commercial product line or product development project, and hence reflect a decline in revenue (or potential revenue) for the firm.

In this section, we have built on existing empirical work to suggest that user communities will be able to provide firms with greater feedback and developmental assistance when supplied with more novel

[3] For example, Cisco Systems released source code for their Cisco Enterprise Print System software (CEPS) so as not to have to provide support for it. These types of contributions result in cost savings for the firm.

knowledge. Feedback from users is known to provide firms with unique and innovative insights that can be used to shape a product's functionality (Chatterji and Fabrizio 2012, Winston-Smith and Shah 2013). And, products that embody novel features or represent radical innovations generate greater financial value for firms than improvements to existing products (Chaney et al. 1991). Therefore, we suggest that the value a firm derives from contributing knowledge to a user innovation community will vary based on the novelty of the knowledge—with more novel knowledge generating greater innovative insights from community participants and hence greater value for the firm.

Hypothesis 2: Contributing more novel knowledge to user innovation communities will generate greater positive stock market returns for firms.

Moderating Value Creation: For Whose Consumption is Knowledge Being Developed?

We suggest that a firm may generate more value by contributing novel knowledge intended for mass market consumers rather than for experts, due to both the size of the commercial market and experts' propensity to compile or build copies of a product themselves. Products intended for mass market consumers tend to target individuals interested in receiving a fully functioning and well supported product (Moore 1991, Rogers 1983). Such consumers tend to make up the majority of the commercial market for the product, and many mass market consumers are willing to pay a premium for value-added features and services. Such individuals are unlikely to innovate, but they are likely to benefit from the insights contributed by innovative users that firms embed into commercial products (Moore 1991, von Hippel 1988) .

In contrast, expert users represent a small and elite set of the market (Moore 1991). Such individuals often possess both the willingness and skill to participate in innovation communities and/or use the knowledge available in innovation communities to assemble their own product (Shah and Mody

2014). As a result, we expect the commercial market for products based on knowledge freely available within a community to be relatively small.[4]

In summary, we expect that contributions of novel knowledge intended for use in products targeted towards mass market consumers, rather than experts, will be expected to generate greater sales revenue, and therefore greater value, for firms.[5]

Hypothesis 3: Contributing novel knowledge will generate greater positive stock market returns for firms when the knowledge is intended for use in products aimed at mass market consumers rather than experts.

METHOD

Our goal is to determine whether or not firms derive value from contributing knowledge to innovation communities and begin to investigate the type of contributions that lead to greater value generation. In order to do so, we use an event study methodology to estimate the abnormal returns to firms' open source code contributions. Event studies gauge the value of a particular action by assessing abnormal returns triggered by press releases. Abnormal returns reflect investors' expectation of the value

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[4] This propensity may be particularly pronounced in the case of virtual products, like software code, where experts (and even more moderately skilled users) can readily download, compile, and run the source code provided by the open source community themselves. In contrast, in the case of physical products, more knowledge and skill relevant to actually *building* the product is required; some, but not all, expert users will be willing to invest the time and effort to do so, especially when they desire customized products.

[5] Some readers may ask why we focus on the moderating effects of the character of the potential consumer base on value generated from the contributions of *novel* knowledge—and not on the value generated from contributions of updated or existing knowledge. As discussed in hypothesis 2, we expect firms to derive little value from contributions of updates or existing knowledge to user innovation communities.

of an action; because investors are the arbiters of the financial value of the firm and its activities, abnormal returns provide a consensus estimate of the value of a particular action to a firm (Aggarwal et al. 2006).

Event studies are widely used in finance, accounting, marketing and management research (Kothari and Warner 2004, MacKinlay 1997, McWilliams and Siegel 1997). A number of studies have used event studies to assess the benefits that firms receive from engaging in innovation activities (Austin 1993). For example, event studies have been used to establish that product development announcements (Sood and Tellis 2009) and new product introductions (Chaney et al. 1991, Fosfuri and Giarratana 2009, Koku et al. 1997, Srinivasan et al. 2009) tend to generate financial value for firms.

Research Setting: Corporate Contributions to Open Source Software Communities

Several characteristics of the open source software context make it a theoretically and methodologically attractive setting in which to examine the value created when firms engage in open and collaborative product development processes. First, of the settings in which community-based innovation has been studied, the most research has been conducted in the context of the software industry. This allows us to build on a number of empirical studies to add insights and rigor to our theory building and improves our ability to interpret results. Second, the software industry is generally free of regulation, meaning that individuals and firms interested in using the contributed code are free to do so. As a result, by releasing code into the commons, firms are truly relinquishing proprietary control over that code. Third, the open source software context is remarkably transparent: firms issue press announcements regarding their contributions to innovation communities, and their contributions can be observed by individuals within and outside the community. This transparency provides a basis for our empirical analysis: event study methodology is predicated on the efficient markets hypothesis, which proposes that the stock price of a company fully reflects all publicly available information about a company (Fama 1965). Fourth, open source community contributions tend to occur in open and publicly accessible online forums, hence it is likely that most corporate contributions are documented by press releases (as it would be difficult for firms to attempt to hide their participation or delay announcements of their contributions).

This gives us reason to believe that press releases provide us with a "paper trail" through which to identify contributions.[6]

Sample

An event is defined as an announcement to release source code under an Open Source Initiative (OSI) approved open source software license. When code is released under such a license, its use—importantly for our purposes—is not restricted and the license automatically applies to all derivative code.[7] Corporations making such code contributions are therefore relinquishing their proprietary rights to the code (*i.e.,* they have ceded any ability they may have had to prevent others from using the code).

We draw data on code contributions from three main sources: Marketwire, PR Newswire and Business Wire. These sources are the leading press wire services through which firms release information to the market and are widely used in event studies pertaining to business-related issues (Solomon 2012).

[6] In contrast, in other product domains, firms may pursue collaboration with communities in less transparent settings (*e.g.,* by working with communities or particularly innovative community members in offline meetings, workshops, and conferences). In such settings, a firm's contributions to communities may be difficult to observe and a firm may choose to not announce their contributions publicly, making it difficult to access the data needed to conduct an empirical study. The accessibility of data may be the reason why OSS is the most common setting for investigating community-based innovation.

[7] The OSI is a public benefit corporation and the community recognized body for reviewing and designating licenses as Open Source Definition (OSD) conformant. There are ten attributes that characterize open source definition compliant licenses (see http://opensource.org/docs/osd). Amongst these are free redistribution ("The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale") and the automatic application of the license to works derived from the code ("The license must allow modifications and derived works, and must allow them to be distributed under the same terms as the license of the original software).

We accessed these data sources through the LexisNexis database. Daily financial data are obtained from Bloomberg/Datastream terminal. Our study covers a thirteen-year time span from January 1st, 1999 through December 31st, 2011.

Because our focus is on gauging the impact of open source software development activities on firms' innovation activities, we focus on press releases in which firms announce the decision to reveal software code in a community context. This allows us to restrict our analysis to situations where firms are actively developing software. We used a multi-step approach to identify relevant press releases. First, all announcements that included the subject term "open source software" and the search terms ("releas*" or "reveal*" or "contribut*") and ("open sourc*" or "source code") in the body were retrieved. Second, we identified announcements pertaining to firms listed on the NYSE, NASDAQ or AMEX. More than 7000 announcements over a period of 10 years were identified in this way. Third, we systematically assessed whether or not each announcement fit our event definition. We established a set of rules by which to identify instances when a firm released software code under an OSI-compliant license and applied this set of rules to each announcement. Each announcement was coded twice to ensure that it fit the event definition. This resulted in the identification of 231 events from 84 different firms. Fourth, it is necessary to exclude events that coincide with confounding events when conducting an event analysis (McWilliams and Siegel 1997). Confounding events include instances where a single company makes another announcement on the same day or one day before or after our focal event occurs. This led us to exclude 76 events.

As a final step, we dropped those 3 events with the highest abnormal returns and 3 with the lowest abnormal returns in order to alleviate the concerns that the results may be influenced heavily on few observations. The final sample consists of 149 events from 64 firms. Our sample size is well within the acceptable range for event studies (McWilliams and Siegel 1997).

Variables

Dependent Variable

We use cumulative abnormal returns (*CAR*s) to measure the value generated when firms engage in community-based innovation development. Cumulative abnormal returns are the sum of the daily, irregular stock market returns abnormal in the days surrounding an event of interest. CARs have been used to measure the value generated from innovative activities in a number of studies (Fosfuri and Giarratana 2009, Sood and Tellis 2009, Srinivasan et al. 2009). They provide a particularly useful measure of innovation for researchers, because they are not subject to manipulation by environmental factors and they reflect how much investors value the new information (McWilliams and Siegel 1997). CARs are a well-regarded measure of the value generated by innovation (Sood and Tellis 2009).

Focal Variables

Our focal variables are designed to capture particular code characteristics. Specifically, we sought to assess the novelty of the code and the commercial audience for which the code was intended. Press releases generally provided extensive information on these characteristics. We devised systematic rules to code each announcement in accordance with each variable definition. In a very small number of instances, a press release provided insufficient information. In such cases, we collected the needed information by examining firm and community web pages.

We use two approaches to proxy for novelty of the code. The first approach involved creating three mutually exclusive, binary variables: *New Code*, *Updated Code*, and *Existing Proprietary Code.* The *New Code* variable takes a value of 1 if the code is altogether new to the market (*i.e.*, the code has not been diffused in the past, either as open source or proprietary source code). The *Updated Code* variable takes a value of 1 if the code is a new version (update) of existing open source or proprietary source code. The *Existing Proprietary Code* variable takes a value of 1 if the code has been sold in proprietary form and is being released under an open source license for the first time (note that consumers have had commercial access to the functionality of source code categorized as *Existing Proprietary Code*, and such code includes no new components or features. Cases where existing proprietary code was updated with new open source components or functionality are classified as *Updated Code;* 5 such cases appear in the sample). The alternative approach involves creating an ordinal variable, *Novelty*, which takes the value 0 if *Existing Proprietary Code* variable is equal to 1, 1 if *Updated Code* variable is equal to 1, and 2 if *New Code* variable is equal to 1. Figure 1 depicts how the code novelty variable is constructed.

We also create codes to identify the target users of the code: experts, generally referred to as developers in the software context, or generalist consumers. Code contributions pertaining to development tools, *Development Tools*, are classified as being primarily for use by developers, whereas code contributions for system software or application software, *System or Application SW*, are classified as being intended for use by consumers. There are three contributions that included code both for use by developers and by consumers; as a result, the *Development Tools* and *System or Application SW* variables are not mutually exclusive.

Controls

We include four sets of control variables in our empirical analysis. The first set controls for characteristics specific to an announcement. *Pre-announcement* is a binary variable that identifies press releases announcing future code contributions (Koku et al. 1997). *Pre-release* is a binary variable that identifies announcements of alpha or beta releases of software that will be released in full form in the future. We control for these two binary variables to avoid our results being diminished by forward-looking statements: announcements for actual products send a more credible signal to the market by enabling investors to differentiate real contributions from "vaporware." "Vaporware" refers to non-existent products that a firm claims are "forthcoming" (Koku 2009).

The second set controls for firm specific characteristics. We control for *Firm Size*, the total number of employees of firm *i* at time *t*, and *Software Patents*, the total number of software patents that firm *i* has been granted with during the five years prior to time *t*, in order to account for firms' endowments of intellectual property rights (IPRs) and complementary assets. We also control for the *OSS Announcement Ratio*, the ratio of the number of press releases that include "open source software" in the subject term to the total number of press releases by firm *i* over the 1-year prior to time *t*. This variable is intended to capture a firm's interest and efforts of engaging in OSS movement (Alexy and George 2013, Hannan et al. 2007).

The third set controls for a firm's technical expertise in developing software (Aggarwal et al. 2006). We introduce five dummy variables for the industry(ies) in which firm *i* operates*:* hardware, software, electronics, semiconductors and telecommunications. We determine these industries by using the SIC code(s) associated with each firm (Fosfuri et al. 2008).

Finally, we introduce year dummies to control for time-variant effects (Alexy and George 2013, Shiller 2000).

Analytic Method

The abnormal return to an event (announcement) is obtained in two steps. First we estimate the normal return, which is the expected return that would have been observed if the event did not take place, for the time period preceding the event. We follow standard practice by using the time period 160 to 5 days prior to the event (Campbell et al. 1997). Normal returns are estimated via Fama-French 3-factor model (Fama and French 1992).[8]

$$(R_{it} - Rf_t) = \alpha_i + \beta_{1i} (Rmkt_t - Rf_t) + \beta_{2i}\, SMB_t + \beta_{3i}\, HML_t + \varepsilon_{it}$$

where R_{it} is the return on shares of firm *i* over the event window *t*, Rf_t is the risk-free rate of return at time *t*, $Rmkt_t$ is the return on all firms in NYSE, AMEX and NASDAQ at time *t*, SMB_t is the index of relative returns for small versus large capitalization stocks at time *t*, and HML_t is the index of relative returns for high versus low book-to-market stocks at time *t*. The size (SMB_t) and book-to-market (HML_t) variables capture information about macroeconomic sources of risk that are of concern to investors and therefore proxy for numerous individual macroeconomic variables for the purposes of econometric analysis, as well as explain most of the cross sectional variation between the returns on NYSE, AMEX or NASDAQ (Black 1993, Cohen et al. 2003, Fama and French 1992, Vassalou 2003).

Next we compute the abnormal return (AR_{it}) by taking the difference between the observed return on the day of the event and the normal return estimated via the benchmark model described above. Thus,

$$AR_{it} = R_{it} - E\,[R_{it}]$$

[8] Available at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_factors.html

where AR_{it} is the abnormal return, $R_{it,}$ is the observed return and $E\,[R_{it}]$ is the normal return for announcement *i* and event window *t*. We compute the cumulative abnormal return (CAR) for each event by aggregating abnormal returns through the event window for each security. The event window, *t*, spans 2 days that include the day of the event and the day before the event occurs, because the effect of the event is strongest around the day of the event (Campbell et al. 1997).

We also investigate the effect of code characteristics on the magnitude of abnormal returns using a cross-sectional regression model:

$$CAR_{it} = \beta_0 + \beta_1\, New\ Code_{it} + \beta_2\, Updated\ Code_{it} + B_3\, Firm\ Size_{it} + B_4\, Software\ Patents_{it} + \beta_5\, OSS\ Announcement\ Ratio_{it} + \beta_6\, Pre\text{-}release_{it} + \beta_7\, Pre\text{-}announcement_{it} + \sum_{s=1}^{5} \beta_s d_s + \sum_{y=1999}^{2011} \beta_y d_y + \varepsilon_{it}$$

where CAR_{it} is the cumulative abnormal return across time *t* for security *i*. *New Code* and *Updated Code* are binary variables that are used for identifying newness of the code. We keep *Existing Proprietary Code* variable as the control group in this model. *Software Patents* and *OSS Announcement Ratio* are used as firm-specific controls. *Pre-release* and *Pre-announcement* are binary variables that account for forward-looking statements in the body of the announcement. Dummy variables d_s and d_y indicate sector and year effects, respectively.

FINDINGS

Table 1 provides descriptive statistics. Correlation coefficients are presented in Table 2. In line with our expectations, the dependent variable (CARs) is positively correlated with contributions of new code, updated code, and system or application software; and negatively correlated with contributions of existing proprietary code and development tools. In line with existing research, pre-announcements and pre-releases are negatively related to the dependent variable (Koku 2009).

Insert Table 1 and 2 about here

Figure 2 and Figure 3 depict the distribution of events and distribution of firms contributing code across years respectively. The trend in Figure 2 does not show a consistent decline or increase. However, there are two declines in the number of announcements worth commenting upon. The first begins in 2001, following the burst of dot-com bubble. The second begins in 2007 and continues through 2008, in parallel with the start of the global financial crises. Figure 3 depicts a more consistent and steady upward trend in the overall number of firms making open source code contributions each year. A decrease in the number of firms does follow the burst of dot-com bubble.

Insert Figures 2 and 3 about here

Table 3 presents the results of the cross section regression analysis in which the dependent variable is the CARs over a 2-day event window and where errors are clustered by firm. We confirm the significance of CARs by using the generalized rank test (Kolari and Pynnonen 2011). The result indicates that the CARs are statistically significant at 0.05 level. The constant term in the first column (baseline model) reflects the CARs generated by code contribution events. The coefficient on the constant term remains positive and significant at the 0.1 level. In the second column we add two sets of control variables to account for announcement characteristics (*Pre-release* and *Pre-announcement)* and firm characteristics (*Software Patents* and *OSS Announcement Ratio)*. The coefficient on the constant term remains large and significant. These findings provide support for *Hypothesis 1:* on aggregate, investors' react positively to source code contributions. The results remain unchanged when we control for firm specific characteristics (*Software Patents*, *OSS Announcement Ratio*) or for the credibility of the announcement itself (*Pre-announcement*, *Pre-release*).

Insert Table 3 about here

Finally, we present a model that includes our focal variables as well as control variables that account for firm size, sector and time effects (Table 3, Columns 3, 4, and 5). In line with *Hypothesis 2*, which suggests that contributing novel code will generate greater value for firms than contributing updates or existing code, we observe that the coefficient on the *New Code* variable is significant at the 0.1 level and the coefficient on *Updated Code* variable is positive, but not significant. The results are in the same direction when we use the ordinary variable, *Novelty,* as an alternative measure to proxy for the newness of the code (Table 3, Column 7). The coefficient on *Novelty* is significant at the 0.1 level supporting *Hypothesis 2*.

To test *Hypothesis 3,* we introduce interaction terms between the categories that define newness of the code (*New Code, Updated Code,* and *Novelty*) and a binary variable that identifies the intended audience of the code (*System or Application Software).* The coefficient on the interaction terms between *New Code* and *System or Application Software* variables is positive and significant at the 0.05 level suggesting that benefits are larger for firms that contribute new code intended for end-users (Table 3, Column 6). The results are in the same direction when we introduce the interaction term between *Novelty* and *System or Application Software* variables (Table 3, Column 8). The coefficient on the interaction is positive and significant at the 0.05 level supporting *Hypothesis 3*.

Robustness Checks

We conduct a robustness check for *Hypothesis 3* by splitting the data into two sub-samples and use the same model to estimate coefficients on the variables that proxy for the newness of the code (Table 3, Columns 2 and 3). The first sub-sample includes those contributions that are intended for use by generalist consumers and the second sub-sample includes those contributions that are intended for use by expert developers. While the coefficient on the *New Code* variable is large and significant at the 0.05 level for the consumer sub-sample, its significance disappears for the developer sub-sample. It is possible to observe a similar trend when comparing the coefficient on *Updated Code* variable across two sub-samples. While for the sub-sample of end-user related contributions it is positive, it becomes negative for the sub-sample of code contributions that are intended for developers. The findings support *Hypothesis 3*, which suggests that, when the contribution is intended for use by end-users, the newer the code the greater benefits it will bring about. The results remain unchanged when we use the *Novelty* variable instead (Table 3, Columns 5 and 6). While the coefficient on the *Novelty* variable is large and significant at the 0.05 level in the column that represents the sub-sample of end-user related contributions, it is insignificant for the subsample of code contributions that are intended for developers. *Hypothesis 3* is supported in light of these findings. These results are present in Appendix A.

Although we account for the informational heterogeneity of announcements by controlling for pre-announcements in our main regression analysis, we re-run the analysis with a reduced sample in which we exclude pre-announcements. By doing so, we eliminate the implicit assumption of homogeneous information (Koku et al. 1997) and assess the rewards to the announcements of actual code contributions. In such cases, open source code contributions are positively rewarded by the market with a 0.97% increase in valuation at a significance level of 0.05. Recalling that the CARs to the code contributions were about 0.66% for the full sample, it is possible to infer that investors react more favorably to actual source code contributions than to pre-announcements of source code contributions that will be made in the future. The result of a cross sectional regression analysis based on the reduced sample suggests that the findings remain unchanged (Appendix B).

Our findings are also robust to organizational aging effects (Sørensen and Stuart 2000, Stinchcombe 1965). When *Firm Age* is introduced as a control variable, the coefficient is insignificant.

DISCUSSION

Our findings show that the knowledge a firm contributes to an innovation community matters: contributing knowledge with different characteristics results in differential levels of value creation. By contributing early-stage ideas to communities, firms provide a generative platform upon which users can contribute knowledge and improve potential product concepts. Firms can gain significant and valuable product development benefits by harvesting such insights. Our findings have implications for the strategy, product development, and user-and community-based innovation literatures.

To date, research has focused largely on documenting the prevalence and importance of user innovation (e.g., Kline and Pinch 1996, von Hippel 1988), and identifying ways in which firms can tap the insights of innovative users, such as the observation of user activities (von Hippel 1988), the lead user method (Lilien et al. 2002, Urban and von Hippel 1988), toolkits for user innovation (von Hippel and

Katz 2002), consulting or licensing arrangements with individual users (Chatterji and Fabrizio 2012), and corporate venture capital investments in user-founded startups (Winston-Smith and Shah 2013). Importantly, the literature provides evidence that knowledge can and does flow between users and firms (Chatterji and Fabrizio 2012, Winston-Smith and Shah 2013). However, the literature has not addressed a key strategic question: do user insights generate *value* for firms? The answer to this question is vital, both for advancing theory and for increasing academic and practical interest in user innovation. In this manuscript, we build theory to explain why knowledge from innovative users generates value for firms. We provide systematic empirical evidence showing that knowledge contributions generate financial gains for firms. We then examine the effects of contributing different types of knowledge to user communities on the value generated. We find that firms generate greater value when they contribute more novel—versus existing—ideas to user communities and when more novel knowledge pertains to product ideas aimed at mainstream—versus expert—consumers. These findings demonstrate the importance and relevance of user communities to the performance of firms, thereby connecting the phenomenon of user innovation to the field of strategic management.

These findings also contribute to the literature on product development. The process by which new products are developed within firms generally begins with market research aimed at identifying the needs of customers and progresses through a number of internal processes by which a firm matches customer needs with its own capabilities to establish a product vision and then designs, produces, advertises, and distributes a product (Brown and Eisenhardt 1995, Prandelli et al. 2008, Taylor 2010). However, from a practical perspective, most new product development attempts fail (Cooper and Kleinschmidt 1986, Prandelli et al. 2008). There are many causes for these problems, and the existing literature has extensively examined issues related to internal dynamics (e.g., Brown and Eisenhardt 1995, Taylor 2010). Our theory and findings suggest another pathway for increasing returns from the new product development process: by working with innovative users and their communities, firms may be able to access better market and technological insights that ultimately generate value. Our findings contribute to the burgeoning literature on open innovation, which suggests that innovation is enhanced when open organizational boundaries enable knowledge flows into the organization (Chesbrough 2003, Saxenian 1996, West and Gallagher 2006). Most work in on open innovation focuses on knowledge flows from other firms and from academic institutions (Arora and Gambardella 1990, Chesbrough 2003), we show that users and their communities provide can also serve as a source of external knowledge that benefits firms.

This paper also contributes to the literature on firm participation in open source software development—and community-based innovation more generally. Scholars have posited that contributions to innovation communities benefit firms indirectly, for example by allowing them to displace competitors in the value chain or offer complementary products and services. Such explanations assume that the knowledge contributed to the community is "lost" to the firm as a direct basis for competitive advantage. Less attention has been paid to the possibility that contributed knowledge can also become a platform upon which novel insights are built. We provide evidence supporting this idea. Furthermore, we extend this work by building theory on how such contributions can constitute a foundation for generating new knowledge.

Finally, our study provides practical guidance for firms as they seek novel insights by working with user communities. We provide firms with both a rationale for why community participation will benefit their innovation processes and guidance pertaining to how to derive particularly beneficial outcomes. Specifically, our findings suggest that firms will benefit more by co-developing novel ideas within user innovation communities than by contributing established ideas, and by co-developing novel ideas targeted at average, rather than expert, consumers. Our findings extend our understanding of the benefits that working with users can provide to firms.

We hope that this manuscript will be the first in a series of papers that investigate how firms can generate value by working in concert with user communities. Much work remains to be done in this area. Ours is a single industry study and future research might wish to replicate and expand these findings in other industries. The community-based model of innovation extends well beyond the domain of software. Innovative communities have been key sources of innovation in fields as diverse as astronomy (Ferris

2003), automobiles (Franz 2005, Kline and Pinch 1996), industrial equipment (Allen 1983, Nuvolari 2004), personal computers (Freiberger and Swaine 2000), and sports equipment (Baldwin et al. 2006, Franke and Shah 2003, Shah 2005). In addition, while we investigate two sets of task characteristics that are of importance to product development within firms—the novelty of the knowledge being developed and the target market for that knowledge—other task and community characteristics—such as whether the community is new or established, firm hosted or externally hosted—remain to be investigated. Finally, a number of firms employ individuals to participate in communities. Such forms of organizational alignment may in fact provide a source of competitive advantage for those firms contributing to and participating in community-based knowledge development by improving the flow of knowledge between organizations (in contrast, firms that choose to less actively participate in communities or simply observe technological developments may not be able to fully understand or interpret the knowledge being shared and may hear of developments later). The collaboration mechanisms that underpin these knowledge transfers are worthy of further study (e.g., Daniel et al. 2011).

A methodological limitation that applies to all event studies applies to this study as well: the firms in our sample are publicly traded and relatively large, thereby increasing the possibility of confounding events (announcements that occur on the same day as announcements of code contributions). In order to prevent biased results, we carefully identified and eliminated those observations that coincided with a confounding event and limited the event window to a maximum of two days.

CONCLUSION

User communities represent a novel organizational form, one in which innovations are developed in an open and collaborative manner and knowledge is shared. Firms are increasingly engaging with users and their communities, a practice that has generated interest amongst scholars for both theoretical and practical reasons. While innovation scholars have long suggested that working with users might benefit firms and much effort has gone into suggesting methods by which firms might tap users' knowledge (e.g., von Hippel 1988), little systematic research documenting the benefits of user knowledge for firms has been conducted and the importance of users and their communities has gone largely unrecognized in the strategy and product development literatures. This study contributes to the literature by showing that firms generate financial value through knowledge exchanges with user communities and by investigating the task characteristics that influence the magnitude of value generated.

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Table 1: Descriptive Statistics

	Obs	Mean	Std. Dev.	Min	Max
1 CAR	149	.788	3.075	-8.255	12.666
2 Novelty	149	.718	.863	0	2
3 New Code	149	.268	.445	0 (n=109)	1 (n=40)
4 Updated Code	149	.181	.386	0 (n=122)	1 (n=27)
5 Existing Proprietary Code	149	.550	.499	0 (n=67)	1 (n=82)
6 System/Application SW	149	.483	.501	0 (n=77)	1 (n=72)
7 Development Tools	149	.523	.501	0 (n=69)	1 (n=80)
8 Software Patents	149	217.732	434.911	0	3027
9 Firm Size	149	8.679	2.303	3.045	12.979
10 OSS Announcement Ratio	149	.066	.071	.003	.377
11 Pre-announcement	149	.181	.386	0 (n=122)	1 (n=27)
12 Pre-release	149	.094	.293	0 (n=135)	1 (n=14)

Table 2: Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1 CAR	1.000											
2 Novelty	0.129	1.000										
3 New Code	0.109	0.903	1.000									
4 Updated Code	0.037	0.154	-0.285	1.000								
5 Existing Proprietary Code	-0.126	-0.924	-0.670	-0.520	1.000							
6 System/Application SW	0.046	0.036	0.020	0.033	-0.044	1.000						
7 Development Tools	-0.012	-0.023	-0.015	-0.017	0.026	-0.960	1.000					
8 Software Patents	0.055	0.010	-0.097	0.244	-0.103	0.003	0.049	1.000				
9 Firm Size	-0.075	0.102	0.055	0.099	-0.126	0.150	-0.106	0.565	1.000			
10 Oss Announcement Ratio	-0.042	0.083	0.081	-0.001	-0.072	0.094	-0.071	-0.092	-0.155	1.000		
11 Pre-announcement	-0.118	-0.069	-0.010	-0.131	0.110	0.033	-0.052	-0.035	0.118	-0.122	1.000	
12 Pre-release	-0.006	-0.001	-0.039	0.087	-0.033	0.057	-0.024	0.025	-0.006	0.150	-0.152	1.000

Table 3: Results of OLS Regression

	Baseline Model		Main Results					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	CAR	CAR	CAR	CAR	CAR	CAR	CAR	CAR
Novelty							0.672*	-0.268
							(0.390)	(0.588)
*Novelty * System/Application SW*								1.866**
								(0.802)
New Code			1.290*	1.474*	1.461*	-0.456		
			(0.763)	(0.836)	(0.821)	(1.163)		
*New Code * System/Application SW*						3.792**		
						(1.606)		
Updated Code			0.259	0.021	0.001	-0.794		
			(0.787)	(0.798)	(0.787)	(1.105)		
*Updated Code * System/Application SW*						1.556		
						(1.905)		
System/Application SW					0.697	-0.590	0.689	-0.633
					(0.628)	(0.962)	(0.624)	(0.874)
Firm Size				-0.000**	-0.000**	-0.000**	-0.000**	-0.000**
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Software Patents		0.000	0.001	0.003**	0.003**	0.003**	0.003**	0.003**
		(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
OSS Announcement Ratio		-2.721	-4.219	-5.355	-5.922	-6.755	-5.584	-6.400
		(5.253)	(4.060)	(3.616)	(3.584)	(3.374)	(3.538)	(3.280)
Pre-announcement		-1.253*	-0.501	-0.325	-0.397	-0.051	-0.363	-0.039
		(0.676)	(0.720)	(0.749)	(0.751)	(0.826)	(0.771)	(0.846)
Pre-release		-0.251	0.576	0.475	0.364	0.393	0.339	0.332
		(1.515)	(1.931)	(1.947)	(1.917)	(1.899)	(1.913)	(1.871)
Sector Dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.696*	1.037**	2.495	2.298	2.007	2.341	2.077	2.442
	(0.383)	(0.506)	(2.040)	2.025	(2.025)	(1.883)	(2.014)	(1.819)
Observations	149	149	149	149	149	149	149	149
R-squared	0.000	0.020	0.132	0.153	0.159	0.195	0.155	0.190

Robust standard errors in parentheses are clustered by firms
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Categorization of Code Novelty

	Licensing Model	
	Open Source	**Proprietary**
New code (n=40)	New Code	**--** [a]
Updates to existing code (n=27)	Updated Code	Updated Code
Existing code (n=82)	**--** [b]	Existing Proprietary Code

[a] Code that was previously released as proprietary cannot be new by definition. Hence this category represents a null set.
[b] Existing code that was already released under an open source license would not be re-released. Hence this category represents a null set.

Figure 2: Open Source Code Releases Across Years

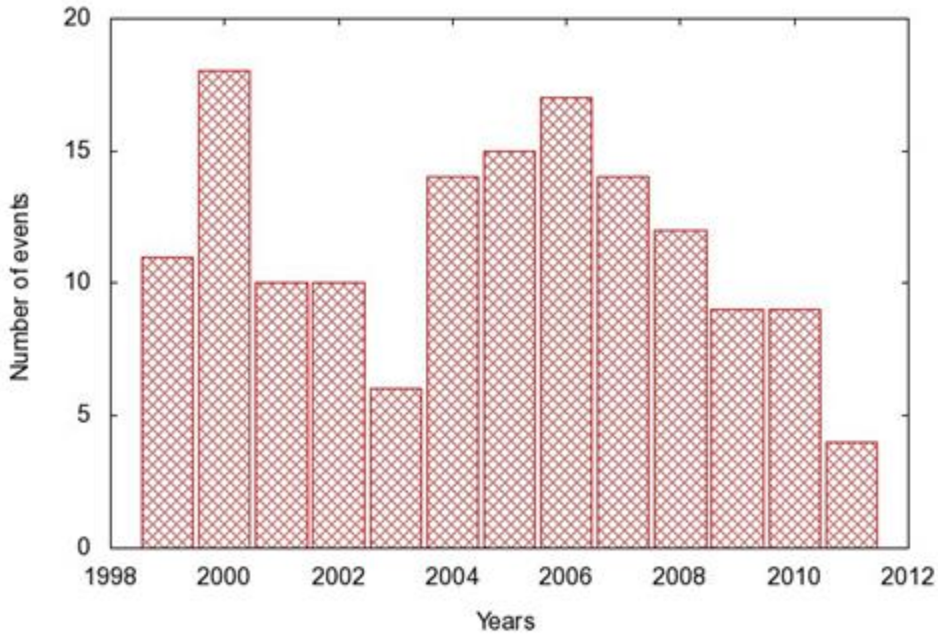
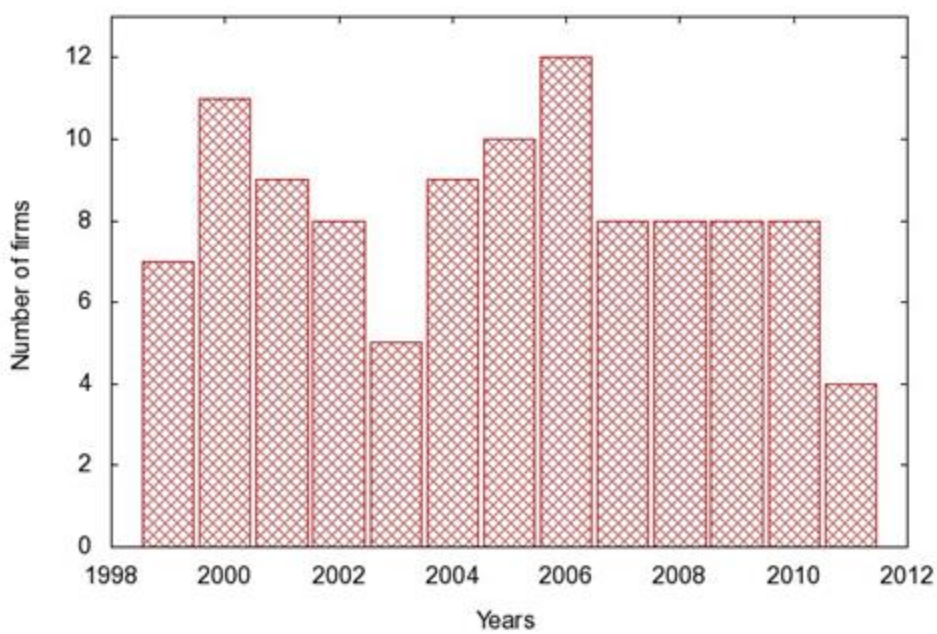


Figure 3: Number of Firms Releasing Open Source Code Across Years



Appendix A: OLS Regression Results for Split Sample

VARIABLES	Full sample CAR	Sys/App SW CAR	Dev. Tools CAR	Full sample CAR	Sys/App SW CAR	Dev. Tools CAR
Novelty				0.680*	1.455**	-0.007
				(0.396)	(0.635)	(0.760)
New Code	1.474*	3.073**	0.319			
	(0.836)	(1.306)	(1.555)			
Updated Code	0.021	0.253	-1.780			
	(0.798)	(1.468)	(1.103)			
Firm Size	-0.000**	-0.000**	-0.000*	-0.000**	-0.000**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Software Patents	0.003**	0.006*	0.004**	0.002**	0.006	0.002*
	(0.001)	(0.003)	(0.001)	(0.001)	(0.003)	(0.001)
OSS Announcement Ratio	-5.355	-6.762	-6.845	-5.029	-6.017	-5.874
	(3.616)	(5.094)	(4.814)	(3.603)	(5.499)	(4.504)
Pre-announcement	-0.325	0.579	-1.091	-0.293	0.518	-0.678
	(0.749)	(1.443)	(1.189)	(0.772)	(1.550)	(1.267)
Pre-release	0.475	0.622	0.065	0.449	0.332	0.241
	(1.947)	(3.774)	(1.017)	(1.944)	(3.719)	(1.107)
Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.298	3.009	1.681	2.363	3.282	1.694
	(2.025)	(2.216)	(2.647)	(2.014)	(2.220)	(2.636)
Observations	149	72	80	149	72	80
R-squared	0.153	0.275	0.302	0.149	0.265	0.279

Robust standard errors in parentheses are clustered by firms
*** p<0.01, ** p<0.05, * p<0.1

Appendix B: Robustness Check - CARs for Announcements of Actual Code Contributions (Excludes Pre-announcement and Pre-releases)

	Baseline Model		Main Results					
			Full sample	Sys/App SW	Dev. Tools	Full sample	Sys/App SW	Dev. Tools
VARIABLES	CAR	CAR	CAR	CAR	CAR	CAR	CAR	CAR
Novelty						0.858*	2.048***	-0.202
						(0.489)	(0.554)	(1.074)
New Code			1.760*	4.093***	0.390			
			(1.015)	(1.142)	(2.411)			
Updated Code			0.623	2.885	-2.222*			
			(0.930)	(1.906)	(1.208)			
Firm Size		-0.000**	-0.000**	-0.000**	-0.000*	-0.000**	-0.000**	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Software Patents		0.001	0.002	0.007	0.003**	0.002*	0.007	0.002
		(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	(0.004)	(0.001)
OSS Announcement		-2.971	-3.372	-5.994	0.403	-3.080	-7.330	3.218
Ratio		(5.036)	(6.218)	(8.219)	(10.990)	(4.747)	(7.350)	(11.339)
Sector Dummies		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.974**	2.095	1.726	4.668*	1.222	1.734	4.723*	1.137
	(0.452)	(2.374)	(2.381)	(2.518)	(2.884)	(2.494)	(2.376)	(2.962)
Observations	107	107	107	49	60	107	49	60
R-squared	0.000	0.202	0.232	0.537	0.388	0.232	0.534	0.358

Robust standard errors in parentheses are clustered by firms
*** p<0.01, ** p<0.05, * p<0.1