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Comparative Study on Innovation Incentives for Commercial Open Source Software under Different Licenses

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Abstract: This study compares technological innovation incentives for commercial open source software under two typical licenses (the GNU General Public License and the Berkeley Software Distribution License, i.e., GPL and BSD). In the case of private optimum, the incentive towards software features (resp. usability) innovation is always higher (resp. lower) under BSD than under GPL. Contrast to the private optimum, the social planner expects more investment in software feature under both BSD and GPL, but less (resp. equivalent) investment in software usability under BSD (resp. GPL).

Keywords: BSD, commercial open source software, GPL, innovation, open source software, software feature, software usability

INTRODUCTION

Since 1990s, the rapid development of open source (e.g., Linux, Apache and Sendmail) is a significant phenomenon in software industries. Open Source Software (OSS) is software, whose sources codes are allowed software developers to share, identify and correct errors and redistribute (O'Reilly, 1999). As we all know, open source software is less user friendly than traditional proprietary software. Now more and more companies build commercial products based on open source software, a good example is Red Hat Inc. According to the definition of Kumar *et al*. (2011), Commercial Open Source Software (COSS) is privately developed software based on publicly available source code. In general, its quality is higher than open source software.

A software quality depends on two components: usability (includes online help, documentation, technical assistance, packaging and other support services) and features (includes functionality, reliability, security etc.) (Choudhary and Zhou, 2007). The COSS firm generates a product through improving the features and/or usability of the existing open source software (Deshpande and Riehle, 2008). When a firm develops software based on publicly available source code, it must follow corresponding open source license. The firm may or may not be required to publicly release the software features it develops in accordance with the terms of the open source license. Two typical open source licenses are the GNU General Public License (GPL) and Berkeley Software Distribution license (BSD) (Laurent, 2004). The COSS firm must open the codes of software features under GPL, while it doesn't have to open under BSD. This gives rise to the following issues. First, under which license firms are more willing to invest in software features (or usability)? Second, from a public policy perspective, are the firm's innovation incentives just the right or too high (too low)? We modify the vertical differentiation model and compare firms' innovation incentives towards software features and usability under GPL and BSD.

The following works are related to our study. Raghunathan *et al*. (2005), Choudhary and Zhou (2007), Lanzi (2009) and Xing (2010) research the quality (or innovation) competition between open source and closed software, however all of them don't consider commercial open source and open source licenses. Sen (2007) investigates the price competition between commercial version of OSS and proprietary software. Although her study relates to commercial open source, it doesn't involve in technical innovation. Dixon (2009) and Riehle (2011) present the core properties of commercial open source business models and discuss how they work, yet they don't analyze how open source licenses affect the innovations of commercial open source software.

In this study, we compare technological innovation incentives for commercial open source software under two typical licenses (the GNU General Public License and the Berkeley Software Distribution License, i.e., GPL and BSD). In the case of private optimum, the incentive towards software features (resp. usability) innovation is always higher (resp. lower) under BSD than under GPL. Contrast to the private optimum, the social planner expects more investment in software feature under both BSD and GPL, but less (resp. equivalent) investment in software usability under BSD (resp. GPL).

THE BASIC SETUP

There are two types of open source software products in a market, one is from the not-for profit

community (called OSS in this study) and the other is from the commercial open source software firm (called COSS in this study). Software users are indexed by their level of technical ability, measured by parameter θ, uniformly distributed with density 1 over interval $[0,1]$. Assume that users with higher level of technical skills have lower θ, while those with lower degree of technical capability have higher θ. Moreover, a user who with lower technical expertise has higher willingness to pay for software usability than a user with higher technical expertise does (Choudhary and Zhou, 2007).

The COSS firm needs to comply with the corresponding open source licenses when develops software based on OSS. This study only considers two types of license most common: GPL and BSD. Under BSD, the indirect utility functions for the generic consumer at $\theta\epsilon[0,1]$ when he/she buys open source software and commercial open source software are respectively given by:

$$u_o = \theta v_o + f_o \tag{1}$$

$$u_c = \theta v_c + f_c - p_c \tag{2}$$

where,

v_o, f_o : The usability and features level of open source software

v_c, f_c, p_c : The usability level, features level and price of commercial open source software

Note that the price of open source software equals zero (i.e., $P_o = 0$) because it can be freely available from open source community.

Under BSD, firm may or may not open the software features codes of its development. For simplicity, this study only considers the case that the firm doesn't open the codes under BSD. We set $v_c = v_o + v$ and $f_c = f_o + f$, where v, f is firm's development of usability and features.

The marginal user who is indifferent between buying OSS and COSS, indexed by $\hat{\theta}$, is given by $u_o = u_c$:

$$\hat{\theta} v_o + f_o = \hat{\theta} v_c + f_c - p_c \tag{3}$$

Solving (3), we obtain:

$$\hat{\theta} = \frac{p_c - (f_c - f_o)}{v_c - v_o} = \frac{p_c - f}{v} \tag{4}$$

Assume the market is full coverage. Hence, the demand functions for COSS firm and open source community are respectively given by:

$$d_c = 1 - \hat{\theta} = 1 - \frac{p_c - f}{v} \tag{5}$$

$$d_o = \hat{\theta} - 0 = \frac{p_c - f}{v} \tag{6}$$

The profit function for COSS firm is given by:

$$\pi_c = p_c d_c - \xi v^2 d_c - \gamma f^2 = (p_c - \xi v^2)(1 - \frac{p_c - f}{v}) - \gamma f^2 \tag{7}$$

where,

$\xi v^2 d_e, \gamma f^2$: The cost of innovation when firm develops the usability and features of open source software

ξ, γ : Positive parameter which measures the innovation efficiency

Under GPL, the indirect utility functions for the generic consumer at $\theta\epsilon[0,1]$ when he/she buys open source software are respectively given by:

$$u_o = \theta v_o + (f_o + f) \tag{8}$$

$$u_c = \theta(v_o + v) + (f_o + f) - p_c \tag{9}$$

Note that the GPL requires COSS firm opens the software feature codes of its development. Moreover we assume open source community can wholly obtain firm's feature codes, so the features level of open source software is also $f_o + f$.

The marginal user who is indifferent between buying OSS and COSS, indexed by $\dot{\theta}$, is given by $u_0 = u_c$:

$$\hat{\theta} v_o + (f_o + f) = \hat{\theta}(v_o + v) + (f_o + f) - p_c \tag{10}$$

Solving (10), we obtain:

$$\hat{\theta} = \frac{p_c}{v} \tag{11}$$

Hence, the demand functions for COSS firm and open source community are respectively given by:

$$d_c = 1 - \hat{\theta} = 1 - \frac{p_c}{v} \tag{12}$$

$$d_o = \hat{\theta} - 0 = \frac{p_c}{v} \tag{13}$$

The profit function for COSS firm is given by:

$$\pi_c = (p_c - \xi v^2)(1 - \frac{p_c}{v}) - \gamma f^2 \tag{14}$$

If the COSS firm is run by a benevolent social planner instead, the software levels of usability and features are chosen to maximize the social welfare, defined as the sum of profits and consumer surplus:

$$SW = \pi_c + CS = \pi_c + \int_0^{\hat{\theta}} u_o d\theta + \int_{\hat{\theta}}^1 u_c d\theta \tag{15}$$

The timing of software quality choosing and pricing is as follows. In the first stage, the COSS firm determines software usability and feature development. In the second stage, it sets price.

THE PRIVATE OPTIMUM

The solutions of the model are derived by backwards induction. The price stage is analyzed firstly and then the quality stage is decided.

Under BSD:

Solution of stage 2: The first-order condition of profit function (7) with respect to P_c is given by:

$$\frac{\partial \pi_c}{\partial p_c} = 1 - \frac{p_c - f}{v} - \frac{p_c - \xi v^2}{v} = 0 \tag{16}$$

Solving (16), we derive the optimal price for COSS:

$$p_c^* = \frac{v + f + \xi v^2}{2} \tag{17}$$

Substituting (17) in (5) and (7), we obtain the demand and profit function for COSS firm:

$$d_c = \frac{v + f - \xi v^2}{2v} \tag{18}$$

$$\pi_c = \frac{(v + f - \xi v^2)^2}{4v} - \gamma f^2 \tag{19}$$

Solution of stage 1: Taking the derivatives of (19) with respect to f and v respectively and then setting them equal to zero, we obtain the following equations:

$$\frac{\partial \pi_c}{\partial f} = \frac{v + f - \xi v^2}{2v} - 2\gamma f = 0 \tag{20}$$

$$\frac{\partial \pi_c}{\partial v} = \frac{(v + f - \xi v^2)(v - f - 3\xi v^2)}{4v^2} = 0 \tag{21}$$

The above equations yield three groups of solution, however only the following one, which meets the second-order conditions, is the optimal improvement of feature and usability under BSD:

$$f_B^* = \frac{2\gamma - \xi - \sqrt{(\gamma + \xi)^2 - 6\gamma\xi}}{6\gamma^2} \tag{22}$$

$$v_B^* = \frac{\gamma + \xi + \sqrt{(\gamma + \xi)^2 - 6\gamma\xi}}{6\gamma\xi} \tag{23}$$

Note that the parameters must satisfy $\gamma \geq (2+\sqrt{3})\xi$ for interior solution exists and two types of software coexist in the market (i.e., $d_0 \in (0,1)$ and $d_c \in (0,1)$). Through (22) and (23), we know that firm has an incentive to invest in both usability and features (i.e., $f_B^* > 0$ and $v_B^* > 0$).

Under GPL:

Solution of stage 2: The first-order condition of profit function (14) with respect to p_c is given by:

$$\frac{\partial \pi_c}{\partial p_c} = 1 - \frac{p_c}{v} - \frac{p_c - \xi v^2}{v} = 0 \tag{24}$$

Solving (24), we derive the optimal price for COSS:

$$p_c^* = \frac{v + \xi v^2}{2} \tag{25}$$

Substituting (25) in (12) and (14), the demand and profit functions for COSS firm are given by:

$$d_c = \frac{v - \xi v^2}{2v} \tag{26}$$

$$\pi_c = \frac{(v - \xi v^2)^2}{4v} - \gamma f^2 \tag{27}$$

Solution of stage 1: Taking the derivative of (27) with respect to f and v respectively and setting it equal to zero, we obtain the following equations:

$$\frac{\partial \pi_c}{\partial f} = -2\gamma f = 0 \tag{28}$$

$$\frac{\partial \pi_c}{\partial v} = \frac{(v-\xi v^2)(v-3\xi v^2)}{4v^2} = 0 \quad (29)$$

Solving (28) and (29), we derive the optimal improvement of feature and usability under GPL:

$$f_G^* = 0 \quad (30)$$

$$v_G^* = \frac{1}{3\xi} \quad (31)$$

Through (22) and (23), we know that firm has no incentive to invest in features, but carry on a lot investment in usability. This result may explain why majority of commercial open source software firms under GPL are more willing to invest in usability, but lack of motivation for the development of functionality.

Comparing the optimal solutions under BSD and GPL, we conclude the following result.

Proposition 1: When $\gamma \geq (2+\sqrt{3})\xi$, there are:

- The COSS firm invests more in software feature under BSD than under GPL (i.e., $f_B^* > f_G^*$)
- The COSS firm invests less in software usability under BSD than under GPL (i.e., $v_B^* > v_G^*$)

Proof:

- $f_B^* = \frac{2\gamma-\xi-\sqrt{(\gamma+\xi)^2-6\gamma\xi}}{6\gamma^2} > 0 f_G^*$ when $\gamma \geq (2+\sqrt{3})\xi$
- $(\gamma+\xi)^2 - 6\gamma\xi = \gamma^2+\xi^2-4\gamma\xi < \gamma^2+\xi^2-2\gamma\xi = (\gamma-\xi)^2$ because of $\gamma > 0$ and $\xi > 0$. Combining $(\gamma+\xi)^2 - 6\gamma\xi \geq 0$ and $\gamma \geq (2+\sqrt{3})\xi > \xi$, we obtain $\sqrt{(\gamma+\xi)^2-6\gamma\xi} < \gamma-\xi$ and then get $\gamma+\xi+\sqrt{(\gamma+\xi)^2-6\gamma\xi} < 2\gamma$. So $v_B^* = \frac{\gamma+\xi+\sqrt{(\gamma+\xi)^2-6\gamma\xi}}{6\gamma\xi} < \frac{2\gamma}{6\gamma\xi} = \frac{1}{3\xi} = v_G^*$

Firm has higher incentive to invest in feature under BSD than under GPL. This is because firm must open the codes when enhances software features under GPL (This reduces the incentive to invest in features), while it needn't open the feature codes under BSD. It is noteworthy that the requirements of open source license on whether to open software feature codes will also affect firm's enthusiasm in software usability investment. When an open source license requires firm must open feature codes, the firm is more willing to focus on improving the software usability. Therefore, firm has higher incentive to invest in software usability under GPL than under BSD.

THE SOCIAL OPTIMUM

We now proceed to decide the level of software feature and usability makes the social welfare maximization. Assume that the price is decided by firm and the social planner only chooses the software usability and feature. Combining (4), (17) and (19), the social welfare function under BSD is given by:

$$\begin{aligned} SW_B &= \int_0^{\hat{\theta}} (\theta v_o + f_o) d\theta + \int_{\hat{\theta}}^1 (\theta v_c + f_o + f - p_c) d\theta + \pi_c \\ &= \frac{3}{8v}(v+f-\xi v^2)^2 + \frac{v_o}{2} + f_o - \gamma f^2 \end{aligned} \quad (32)$$

Differentiating (32) with respect to v and f, respectively and setting them equal to zero:

$$\frac{\partial SW_B}{\partial f} = \frac{3}{4v}(v+f-\xi v^2) - 2\gamma f = 0 \quad (33)$$

$$\frac{\partial SW_B}{\partial v} = \frac{3}{8v^2}(v+f-\xi v^2)(v-f-3\xi v^2) = 0 \quad (34)$$

The socially optimal improvements of usability and feature under BSD are given by:

$$f_B^S = \frac{2\gamma - \frac{3}{2}\xi - \sqrt{(\gamma+\frac{3}{2}\xi)^2 - 9\gamma\xi}}{4\gamma^2} \quad (35)$$

$$v_B^S = \frac{\gamma + \frac{3}{2}\xi + \sqrt{(\gamma+\frac{3}{2}\xi)^2 - 9\gamma\xi}}{6\gamma\xi} \quad (36)$$

Note that the parameters must satisfy $\gamma \geq (3+\frac{3\sqrt{3}}{2})\xi$ for interior solution exists and two types of software coexist.

Combining (11), (25) and (27), the social welfare function under GPL is given by:

$$\begin{aligned} SW_G &= \int_0^{\hat{\theta}} (\theta v_o + f_o + f) d\theta + \int_{\hat{\theta}}^1 (\theta v_c + f_o + f - p_c) d\theta + \pi_c \\ &= \frac{3v}{8}(1-\xi v)^2 + \frac{v_o}{2} + f_o + f - \gamma f^2 \end{aligned} \quad (37)$$

Differentiating (37) with respect to v and f, respectively and setting them equal to zero:

$$\frac{\partial SW_G}{\partial f} = 1 - 2\gamma f = 0 \tag{38}$$

$$\frac{\partial SW_G}{\partial v} = \frac{3}{8}(1 - \xi v)(1 - 3\xi v) = 0 \tag{39}$$

The socially optimal improvements of usability and feature under GPL are given by:

$$f_G^S = \frac{1}{2\gamma} \tag{40}$$

$$v_G^S = \frac{1}{3\xi} \tag{41}$$

A brief comparative assessment of the two regimes (profit-seeking firm and social planning) is now in order. We obtain the following result.

Proposition 2: When $\gamma \geq (3 + \frac{3\sqrt{3}}{2})\xi$, there are:

- The private optimum of usability improvement is more than (resp. equal to) the social optimum under BSD (resp. GPL) (i.e., $v_B^S < v_B^*$ and $v_G^S < v_G^*$)
- The private optimum of feature improvement is less than the social optimum under both BSD and GPL (i.e., $f_B^* < f_B^S$ and $f_G^* < f_G^S$)

Proof:

- In order to prove $v_B^S < v_B^*$, we only need prove $\frac{\xi}{2} + \sqrt{(\gamma + \frac{3}{2}\xi)^2 - 9\gamma\xi} < \sqrt{(\gamma + \xi)^2 - 6\gamma\xi}$ + (equivalent to$\left(\frac{\xi}{2} + \sqrt{(\gamma + \frac{3}{2}\xi)^2 - 9\gamma\xi}\right)^2 < (\gamma + \xi)^2 - 6\gamma\xi$). This translates to prove $\sqrt{(\gamma + \frac{3}{2}\xi)^2 - 9\gamma\xi} < 2\gamma - \frac{3}{2}\xi$. $2\gamma - \frac{3}{2}\xi > 0$ when $\gamma \geq (3 + \frac{3\sqrt{3}}{2})\xi$, so we only need prove $(\gamma + \frac{3}{2}\xi)^2 - 9\gamma\xi < (2\gamma - \frac{3}{2}\xi)^2$. This is equivalent to prove $0 < 3\gamma^2$. Because $0 < 3\gamma^2$ is obvious, $v_B^S < v_B^*$. Moreover, $v_G^S = \frac{1}{3\xi} = v_G^*$.
- Setting $f(v) = v - 3\xi v^2$, we obtain $\frac{df(v)}{dv} = 1 - 6\xi v < 0$ when $v > \frac{1}{6\xi}$. It can be proven $f_B^* = v_B^* - 3\xi(v_B^*)^2$ and $f_B^S = v_B^S - 3\xi(v_B^S)^2$ and $\frac{1}{6\xi} < v_B^S < v_B^*$, So $f_B^S > f_B^*$. Moreover, $f_G^* = 0 < \frac{1}{2\gamma} = f_G^S$.

Proposition 2 demonstrates that, Contrast to the social optimum, the firm invests too little in software feature under both BSD and GPL, too much in software usability under BSD and just the right in the software usability under GPL. Therefore, the social planner necessarily distinguishes the types of open source license and innovation so as to make a correct public policy.

CONCLUSION

The main result of this study is as follows. The COSS firm's incentive towards software feature innovation is higher under BSD than under GPL and incentive towards software usability innovation is lower under BSD than under GPL. From a public policy perspective, the COSS firm's incentive towards software feature innovation is too low under both BSD and GPL and incentive towards software usability innovation is too high under BSD and just the right under GPL.

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