Piracy and Outlaw Community Innovations*

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1 Introduction

It is widely recognised that user innovation occurs in various industries where users modify or improve products that they use (von Hippel 1988, 2005). Communities of user innovators – innovation communities – provide platforms for users to openly and voluntarily communicate with each other regarding innovations they are working on either collectively or independently (Franke & Shah 2003, Hienerth 2006, von Hippel 2005). As user communities have the potential to be leveraged by firms for innovation management, recent empirical work in this area have focussed on how firms and innovation communities can co-exist in a symbiotic relationship from which both users and manufacturers benefit (Jeppesen & Molin 2003, Mayrhofer 2005, Jeppesen & Frederiksen 2006, Prügl & Schreier 2006, Jokisch 2007).

There may, however, exist another type of relationship where community innovations are beneficial for users and at the same time *harmful* for manufacturers. Examples of such a relationship are situations where innovations stemming from user communities aim at bypassing legal or technical safeguards that prevent users from unsolicited usage of the manufacturer's products (Mollick 2004). In particular, manufacturers of electronic devices often embed security mechanisms in their products in order to prevent users from executing unauthorized software code or unlawful obtained (often DRM-protected) content on their platform (such as pirated copies of authorized software or illegal copies of MP3s). Research on user innovations that deactivate such security mechanisms was first analyzed by Mollick (2004). Extending this research, Flowers (2008) introduced the concept of *outlaw innovation* and provided case studies of how communities create and disseminate innovations that not only conflict with manufacturers' intensions of the usage of the original product but also violate firms' intellectual property rights. He proposes that outlaw communities often consist of both users who innovate and those who simply adopt and use outlaw innovations. Recent examples of such outlaw communities in the consumer electronics industry include www.xbox-scene.com, www.xbox-linux.org or www.free60.org for the Microsoft XBOX (a gaming console); www.iphonehacks.com for Apple's iPhone (a mobile phone); and www.cellphonehacks.com for cell phones in general. In the examples listed above, user innovators were able to 'hack' (disable) security mechanisms enabling them (and other users who adopted the hack[1]) to run both user written software code (innovations) and pirated programs on the now unprotected hardware.

Although Flowers (2008) describes how innovative activities of outlaw users are coordinated and communicated within user communities, he does not provide detailed information on the incentives and motivations of individual users to participate in outlaw community innovation communities. The user innovation literature – in particular

[1]In general, adopters have to install small pieces of software on their devices which disables the embedded security mechanism.

literature on the open source movement, see Section 2 – identifies major motivational determinants of individual's participation in innovation projects and analyzed the benefits from the existence of community driven innovations for innovators. However, it is not clear a priori to which extent the results from this literature can be carried over to the context of outlaw innovation. As described above, outlaw innovation may involve activities like infringing third parties IP rights and enabling other community members to engage in undesirable behavior like running illegal copies of copyright protected software or media content. Therefore outlaw innovation can easily exceed legal limits and innovators as well as adopters face the risk of legal prosecution which is not the case in user communities that have been studied sofar. This major difference in the nature of the user innovations might lead to a different motivational structure of innovators and adopters. It should be noted, however, that not all user innovations brought forward in outlaw innovation communities aim at enabling or facilitating illegal behavior harming the manufacturer. Many innovations aim at providing users with an enhanced functionality not offered by original product. From the manufacturers perspective it is important to understand the role of outlaw innovation communities in promoting illegal activities among community participants. In our study we aim at shedding some light in the latter issue while we analyze motivational determinants of community participants in a companion paper.

In this paper, we present results which are based on an online-survey of users an outlaw communities focusing on Microsoft's XBox. In total, we received 1,396 fully completed questionnaires from an online-survey posted at `www.xbox-scene.com` targeting participants of this innovation community. About 21% of the responses originated from users who actively contributed to modifications of original software or to self-written (so called home-brew) software and therefore can be classified as user innovators. Based on this data, we examine the extent to which participants of the community rely on the innovations brought forward by user innovators to run pirated (unlawfully obtained) software which is only possible after a modification of the XBox. We find that the average community member has pirated about 63% of all video games owned by him. In a Tobit regression controlling for demographic factors like users' age or education, we find users' innovative activities to be a significant determinant of piracy behavior: Users who actively innovate by providing 'hacks' or self-written software own significantly less pirated software than users who simply adopt innovations provided by the community. Moreover, we find that active participation in the community reduces the users' tendency to pirate software.

The remainder of the paper proceeds as follows. In Section 2 we review the existing literature on innovation which is developed within user communities. Section 3 describes our object of study, the Microsoft XBox and the relevant user community `www.xbox-scene.com`. A multivariate analysis of users' piracy behavior is presented in Section 4. Finally, section 5 concludes the paper with a summary of the most important

findings of our study.

2 Innovation in user communities

It is generally accustomed to think that innovations are generated by those firms which produce the respective goods. However, research has shown that under certain circumstances innovations come from sources along the value chain other than the manufacturer, in particular from users (von Hippel 1988). Empirical studies covering a broad range of industries from scientific instruments to semiconductors and printed circuit board process, pharmaceuticals, automobiles, sports equipments, statistical software and videogames have shown that innovations in these markets do also stem from users (von Hippel 1988, Franke & Shah 2003, von Hippel 2005, Sawhney et al. 2005, Mayrhofer 2005, Jeppesen & Frederiksen 2006, Jokisch 2007).

Literature that have examined the phenomenon of user innovation in the late 1980s to early 1990s have focussed their unit of analysis on industrial firms as user innovators. Specifically, they suggest two main reasons as to why users innovate. First, users innovate because they obtain the highest benefit from the innovation, that is they have an *urgent need* that is not satisfied by any product currently available on the market (von Hippel 1988, Riggs & von Hippel 1994). Second, users innovate because the information about the underlying problem and possible solutions is often difficult to transfer to the manufacturer - the information is "sticky[2]" (von Hippel 1994). Thus, it may be more economical to develop the innovation themselves.

More recent research in the last decade on user innovation have started to explore the innovative potential of individual end-users. In particular, it was found that individual users often have limited resources to develop their prototyped innovations themselves, and that these restrictions can be overcome when users organise themselves in user communities to assist each other in their innovative endeavors (Franke & Shah 2003, Shah 2005*a*,*b*). Such user communities can be defined as horizontal user networks that consist of user nodes interconnected by information transfer links which may involve face-to-face, electronic or any other form of communication that provide members sociability, support, a sense of belonging, and social identity (Wellman et al. 2002, von Hippel 2007). Three conditions are necessary for user communities to function entirely independently of manufacturers: 1) some users innovate, 2) some users freely reveal[3] their innovations, and 3) users can self-manufacture their innovations

[2]The stickiness of a given unit of information in a given instance is defined as the incremental expenditure required to transfer that unit of information to a specified locus in a form usable by a given information seeker. When this cost is low, information stickiness is low and vice versa. (von Hippel 1994)

[3]"Free revealing" is defined as the granting of access to all interested agents without imposing any direct payments.

relatively cheaply (von Hippel 2007).

The most prominent example of innovation in user communities is that of open source software development. The open source software movement was initiated by software hackers in the late 1990s to promote open collaborative projects between software developers (Raymond 1999). Since its founding, many researchers have been interested in the motivations that drive software developers (user innovators) to contribute their software code (user innovations) to open source software projects. Theoretical and empirical studies show that these incentives for contribution can be categorised into intrinsic and extrinsic motivations. Extrinsic motivation refers to the separable outcome (or indirect reward) that is attained when an activity is done, whereas intrinsic motivation is the inherent satisfaction of the doing of an activity (Ryan & Deci 2000). Examples of extrinsic motivations include skill improvement through active peer review (Hars & Ou 2001, Ghosh et al. 2002) and the signaling motive for career advancements and/or future career benefits (Lerner & Tirole 2001, 2002). Creativity (Lakhani & Wolf 2005), fun (Torvalds & Diamond 2001, Lakhani & Wolf 2005, Bitzer et al. 2004), reputation (Raymond 1999, Ghosh et al. 2002, Lakhani & Wolf 2005), altruism (Zeitlyn 2003, Bitzer et al. 2004) and reciprocity (Lakhani & von Hippel 2003) are examples of intrinsic motivations.

In our study, we focus on one type of community user innovation - hacking (outlaw innovation), which refers to user modifications of a product to not only gain unauthorised access to the product's system but to also enable the user to use the system more effectively (Meyer 1989). Specifically, such hacker communities can be referred to as outlaw communities which consist of groups of users who create (user innovators) and disseminate (adopters) innovations that not only conflict with manufacturers' intentions of the usage of the original product but also violate firms' intellectual property rights (Flowers 2008). Studying four outlaw communities, Mollick (2004) finds that user innovators are often intrinsically motivated by curiosity and creativity, rather than for the sake of theft. Contrary to user innovators, adopters tend to be "vandals" who are motivated to adopt an outlaw innovation to gain unauthorised access to their product's system for pirate behaviour. Despite these motivational differences, the user innovators are willing to allow the adopters to use their innovation so as to gain attention to their work and to give them a certain sense of satisfaction.

Outlaw communities thus have the potential to facilitate the development and diffusion of user innovations which can be used to bypass security mechanisms and finally to enable users to engage in pirate behavior which they could not without adopting these innovations. It should be noted however, that in general outlaw communities do not provide the possibility to download the software necessary to bypass security mechanisms (which would be classified as illegal behavior in some jurisdictions) but only software which can be run on a system which has already been hacked.[4] To engage

[4]In addition to not providing potentially illegal files for download, outlaw innovation communities

in the actual act of piracy users have to download their illegal files from other internet sites.[5] To a large extent, information provided within typical outlaw innovation communities focuses on homebrew software providing functions to the user which are not offered by the manufacturers. It is therefore not clear a priori whether and to which extent participants of outlaw user communities are interested in merely extending the functionality of their hardware vs. obtaining the possibility to engage in pirate behavior. Although there exist various studies examining innovation in outlaw communities (Meyer 1989, Mollick 2004, Flowers 2008), there is no clear evidence on how users' participation in outlaw communities is related to pirate behavior. This study thus aims at examining the impact of outlaw communities on software piracy by analyzing a prominent outlaw user innovation community for Microsoft's XBox.

3 Research design and description of variables

3.1 Object of study – the case of Microsoft's XBox

Many outlaw user innovations occur in the context of consumer electronic equipment. In general, innovations in this settings are based on attempts to manipulate or to replace the embedded operating system in order to extend the limited set of functions provided by the manufacturer with additional functions or to disable security mechanisms to allow for the execution of unauthorised pieces of software as well as illegal copies of authorised software. The manipulations of the firmware which bypasses security mechanisms largely resembles the hacking of computer systems and is therefore often regarded as an outlaw activity (see Flowers (2008) for a more detailed discussion). Known examples of products where users provided modifications or hacks of the embedded operating system range from mobile phones (Apple's iPhone has been hacked in order to allow for the execution of not authorised third party applications[6], to hard-disk based VCRs[7] and also network controllers[8]).

It should be noted though that video gaming consoles provide a particularly attractive target for user modifications for several reasons: First, gaming consoles are in general powerful computing devices which are often equipped with high performance CPUs and graphic processors in order to cope with computational intense high-definition graphics of video games. As a consequence, gaming consoles can in princi-

also ban any discussions or links where those illegal files can be found on the internet.

[5]Often there are distinct internet sites providing this information which is not available within innovation communities.

[6]See `http://www.iphonehacks.com` for more details. Latest visit on March 26^{th} 2008.

[7]See `http://www.lugod.org/presentations/tivohacks` for more details. Latest visit on March 26^{th} 2008.

[8]See `http://www.nslu2-linux.org/wiki/Unslung/HomePage` for more details. Latest visit on March 26^{th} 2008.

ple execute a wide range of different applications without running into computational restrictions. Second, gaming consoles are often sold at a subsidised price as manufacturers anticipate significant revenue streams from complementary products such as software, games or controllers (Soghoian 2007). In many cases, purchases of hardware with similar technical specifications would be possible only at higher prices.

While user modifications exist for almost all major video gaming consoles (Grand et al. 2004), we will focus on Microsoft's XBox for a number of reasons.[9] When it was released in 2001, the XBox was equipped with a 733-MHz Intel Celeron processor, a nVidia GeForce GMX Graphics Processing Unit running at 233 MHz, a 100 MBit/ second ethernet interface and a 10 GB hard disk (see Grand et al. (2004) for a detailed description of the technical specifications of the XBox). This configuration easily topped even upper-scale desktop computers sold at the same time.[10] Despite offering immense computational power, the initial recommended price of an XBox was relatively low with USD 299,- in the US as compared to personal computers with a similar performance.[11] Due to the PC-like architecture and its comparably low price, the XBox quickly drew the attention of user innovators trying to disable Microsoft's security mechanism which was eventually hacked at the end of 2001 (Takahashi 2002). As a consequence, users where able to execute non-authorised software (including illegal copies of authorised software) on the XBox given that they applied appropriate hacks to disable Microsoft's security mechanism.[12]

After the XBox's security mechanism was hacked, numerous pieces of software provided by individual users emerged (so called *homebrew* software). As it would be far beyond the scope of this paper to provide a detailed overview on the XBox homebrew-scene as a whole, we restrict ourselves to the organisation of developers and adopters of homebrew software in internet-based communities where information on the software is discussed and distributed. The development of homebrew software within these communities often follows the principles of open source software development where a larger group of developers collaborate on a larger software suites which source code is put into the public domain. One of the most successful homebrew applications for Microsoft's XBox is the XBox Media Center (XBMC) (see `www.xbmc.org` for a detailed description) – a very powerful and comprehensive multi-media application providing possibilities to store, administrate and play different types of multi-media files including audio and video files. Note that the original XBox firmware provided

[9]We focus on the first-generation XBox. The current version of the XBox ('XBox 360') was introduced in December 2005.

[10]Due to the comparably long life cycles of gaming consoles – for example, the XBox was sold until 2005 with an unchanged hardware configuration – manufacturers include state-of-the-art technology when launching new products.

[11]See `http://en.wikipedia.org/wiki/XBox`, latest visit February, 26^{th}, 2008.

[12]The XBox's security mechanism can be disabled by overwriting an internal flash memory chip, by adding an additional chip or by applying a software-based hack.

by Microsoft provides only very limited possibilities to exploit the multi-media skills of the XBox's hardware. It offers the possibility to play and store music from CDs inserted directly to the XBox with limited functionality with regard to manage larger collections of songs. The playback of DVDs is only possible if an additional controller has been purchased by the user. The XBMC extends this limited set of multi-media skills of the XBox with various functions and can therefore be seen as users' efforts to increase the set of available functions. It is worth emphasising that the collaborative effort in this project yielded a multi-media package whose quality is above the standard of comparable players provided for PC operating systems – in fact, the XBMC is so successful that it has even been ported to the Apple OS.

3.2 Survey design

In order to address the issue whether and how participation in outlaw community innovation is related to the degree of pirate behavior of users, we conducted an online survey of the largest internet community focussing on homebrew software for the XBox. We surveyed participants of the online community `www.xbox-scene.com` using an anonymous online questionnaire hosted on servers of the University of Munich between March, 15^{th} and April 3^{rd} 2005. The questionnaire had been developed based on a series of interviews of active developers of XBox modifications including the webmasters of the online community whose members we surveyed. According to `www.XBox-scene.com`'s website,

> "XBox-scene's primary goal is to keep it's visitors up-to-date about the XBox Scene. Unlike other sites , software pre/reviews aren't [...] major sections. XBox-Scene is specialized in hardware news and information. [XBox-scene] will talk about mods (modifactions) and other hardware aspects."[13]

Our survey was advertised prominently on the web pages and resulted in a total of 1,396 complete responses. As data on the size of the basic population was not available we are unable to report a precise response rate. However, we conducted a non-response analysis comparing early to late respondents (Armstrong & Overton 1977) which yielded no indication of a non-response bias.[14]

In our study, outlaw community members are defined as members who have modified their XBox to circumvent the XBox's security mechanism so as to be able to execute software which is not authorised by Microsoft (homebrew software and illegal

[13]See `http://www.XBox-scene.com/about.php` for more details, latest visit on February, 26^{th}, 2008.

[14]In particular, we compared the first 10% with the last 10% of the responses to our survey with regard to the means of relevant variables using T-tests. The observed differences are not significant and does not point to systematic differences between early and late responses.

copies of authorised software). All respondents to our survey are male and between 14 and 61 years old. The average age of our respondents is 23 years. Although most of the respondents have a college degree or higher (43%), about a fifth of them are still in school and approximately a third of them have only a high school degree. The majority of the respondents came from North America (U.S. 47.9% of all respondents and Canada 9.7% of all respondents). The remaining respondents are distributed more or less equally across Europe and the Asian-Pacific region. A more detailed description of our dataset will be made available in a companion paper to this work.

3.3 Variables and descriptive statistics

Dependent variable

We are interested in analyzing a users willingness to engage in pirate behavior in order to get a clearer picturer of the role that outlaw user innovation communities play in this context. It should be noted, however, that an individual's inclination to engage in pirate behavior can not be observed or measured directly. It is an unobservable latent variable. In the context of our study we therefore rely on a measure of users' inclination to engage in piracy behavior which is directly linked to observable piracy behavior. We asked the users to indicate how many games they own – irrespective from which sources the games were obtained. Further, respondents were asked to report the number of games which can be considered 'original'. Based on these two questions we compute the share of original games relative to the total number of games owned by a user as well as the share of pirated (non-original) games. The latter ratio should – everything else being equal – be highly correlated with a user's unobservable inclination to actively engage in pirate behavior.

Table 1 reports summary statistics of our dependent variable and indicates that the average share of pirated games across all respondents is about 63.8%. Distinguishing the group of user innovators who actively contribute to the development of modifications for the XBox (about 21.0% of all respondents) from the adopters reveals a significant difference. The share of pirated games is about 6% points higher for the adopters and the difference is significantly different from zero.

Table 1: Share of pirated copies of games relative to all games owned by respondents. Note: A t-test rejects the hypothesis that the difference in the average share of pirated between adopters and innovators is equal to zero at the 1% level of significance.

Share of pirated games	**Obs.**	**Mean**	**SD**	**Median**	**Min**	**Max**
Adopter	1,124	0.650	0.349	0.800	0	1
User innovator	272	0.589	0.367	0.730	0	1
Total	**1,396**	**0.638**	**0.354**	**0.778**	**0**	**1**

Independent variables

We assume that apart from the participation in the innovation community other variables play a crucial role in determining an individuals inclination to engage in pirate behavior. In the following we describe in more detail which measures we use in order to model users pirate behavior empirically.

User innovator (0/1): As noted earlier by Mollick (2004), participants in outlaw communities can be distinguished in two groups: user innovators which actively contribute to the development of innovations (in our case software code for the XBox) on the one hand and mere adopters of the innovations on the other hand. In our survey we ask respondents to indicate whether they have already contributed to the development of unauthorized software code[15] for the XBox. We classify respondents answering "yes" as user innovators. In our sample we find 19.48% of participants to be user innovators.

Total number of games owned: We assume a positive relation between pirate behavior and total number of games owned by a respondent. This hypothesis is based on the assumption that respondents owning a large number of games have larger monetary benefits (savings) if they pirate a certain share of the games they want to own compared to respondents which only own few games.

The average respondent in our sample owns in total about 58 games, see Table 2. Again, we observe significant differences between adopters and user innovators: adopters own on average about 14 games more than respondents which actively contribute to innovative activity in the community. Moreover, we observe a highly significant positive correlation (correlation coefficient 0.32) between the total number of games of games owned by an individual and the share of pirated games. We interpret the positive correlation as first evidence of the validity of our assumption that monetary benefits from pirating are positively related with the degree of piracy observed.

Table 2: Number of all games owned by respondents irrespective whether they were obtained legally or not. Note: A t-test rejects the hypothesis that the difference in the average share of pirated between adopters and innovators is equal to zero at the 1% level of significance.

Total number of games	**Obs.**	**Mean**	**SD**	**Median**	**Min**	**Max**
Adopters	1,124	55.506	66.591	36.5	1	500
User innovator	272	69.757	81.022	45.5	1	450
Total	**1,396**	**58.283**	**69.835**	**40**	**1**	**500**

[15]This includes both the modification of authorised software code as well as the development of unauthorised software code (homebrew software).

Hacking as very important reason to hack the XBox (0/1): We include a dummy variable indicating whether the possibility to run illegal copies of games on the XBox was indicated as a "very important" reason to hack the XBox by our respondents. The dummy variable is included into the regression analyses as respondents motivations to modify their XBox are very likely to be correlated with both the left-hand side and also the right-hand side variables of our regressions – leaving them out could potentially create an omitted variable bias.

Socio-legal attitudes: It is a natural assumption that personal traits and in particular socio-legal attitudes determine individual behavior. As we are interested in a person's engagement in pirating copyright protected materials (video games) attitudes towards the protection of immaterial goods are especially important. Unfortunately, there is no scale for the measurement of attitudes towards copyright protection established in the literature. We therefore develope a scale consisting of five items all relating to a person's attitude towards the protection of immaterial goods in our questionnaire (see Appendix A.1). Results of a principal component analysis reveal that all items load on one factor with Eigenvalue greater than 1. Based on the respondents' answers to these items we construct an equally weighted index of a person's attitude. Cronbach's alpha for this index is 0.61 which is acceptable for newly developed scales in exploratory studies (see Nunnally (1978) for a discussion of the interpretation of Cronbach's alpha in different research settings). User innovators seem to respect copyright protection slightly more than adopters (see Table 3). However, the difference between the two groups of community participants is only significant at the 10% level. The coefficient of correlation between a person's attitude and the share of pirated games is negative (-0.30) and highly significant.

Table 3: Index of personal attitude towards piracy protection. Note: The index ranges from 1 (low respect of copyright protection) to 5 (large respect of copyright protection). A t-test rejects the hypothesis that the difference in the average share of pirated between adopters and innovators is equal to zero at the 5.7% level of significance.

Index of person's attitude towards copyright protection	**Obs.**	**Mean**	**SD**	**Median**	**Min**	**Max**
Adopters	1,124	3.046	0.021	3	1	4.8
User innovator	272	3.122	0.046	3.2	1	5
Total	**1,396**	**3.061**	**0.019**	**3.1**	**1**	**5**

Community activity: In our questionnaire we asked respondents to indicate how often they interact with `xbox-scene.com` when performing different activities ranging from simply visiting the website to actively participating in forum discussions. The principal component analysis results of the six items relating to the frequency of participation in different activities show that all items load on one factor with Eigenvalue

greater than 1 and we construct an equally weighted index of a person's community activity by applying weights of 1/6 to the items. Cronbach's alpha for this scale is high with 0.91. We find user innovators to be significantly more active in terms of community participation than adopters (see Table 4).

Table 4: Index of participation in community. Note: The index ranges from 1 (low level of participation) to 5 (high level of participation). A t-test rejects the hypothesis that the difference in the participation index between adopters and innovators is equal to zero at the 1% level of significance.

Community participation	**Obs.**	**Mean**	**SD**	**Median**	**Min**	**Max**
Adopters	1,124	1.383	0.495	1.167	1	5
User innovators	272	1.637	0.692	1.5	1	5
Total	**1,396**	**1.432**	**0.548**	**1.333**	**1**	**5**

In addition to analyzing the mere effect of community activity on pirate behavior we also include an interaction term between community activity and the user innovator dummy variable into a second set of regressions. We do so in order to analyze whether user innovators which are very active in an community are behaviorally different from user innovators who do not actively participate in the innovation community as our interview evidence suggests.

Knowledge of hackability of XBox at purchase: Pirate behavior of respondents might be influenced by their degree of knowledge and skills with regard to the technical modifications necessary for the implementation of the modifications of the XBox allowing the execution of pirated software. It is reasonable to assume that not all community members knew about the possibility to modify the XBox when purchasing while the hackability was a major reason to buy the XBox for other participants.[16] Prior knowledge of hackability might be correlated both with the degree of piracy users exhibit and with one or more of the other independent variables. Thus, to avoid an omitted variable bias, we include a dummy variable indicating users who were aware of hackability. These are about 62.6% of all users.

XBox modification: The disablement of the XBox's security mechanism requires some technical knowledge either with regard to hardware modifications like soldering in a mod-chip or how to apply available software hacks. It is likely that not all of the respondents are knowledgable enough to perform the necessary modifications on their own. In fact, the responses indicate that about 30% of the participants did not modify their XBox on their own but either with the help of somebody else or getting it done by professional service providers. Table 5 indicates significant differences between user

[16]In fact, 84% of all users who were aware of the hackability of the XBox answered that this was an "important" or "very important" reason to buy the Xbox.

innovators and adopters – user innovators are more likely to perform the modifications on their own.

Table 5: Share of respondents who modified there XBOX without third-party help. Note: A t-test rejects the hypothesis that the difference in the the share of respondents who performed the modification on their own between adopters and innovators is equal to zero at the 1% level of significance.

Modification of the XBox performed on their own	**Obs.**	**Mean**	**Median**	**Min**	**Max**
Adopter	1,124	0.673	1	0	1
User innovator	272	0.783	1	0	1
Total	**1,396**	**0.694**	**1**	**0**	**1**

Age: Pirate behavior is also likely to be influenced by the age of the user. Respondents were asked to report their age in the questionnaire and Table 6 presents descriptive statistics with regard to age. The average age of our respondents is 23.5 years. Interestingly, user innovators are younger than adopters in our sample and the difference is significantly different from zero on the 5% level.

Table 6: Age distribution of respondents. Note: A t-test rejects the hypothesis that the difference in the the average age of the respondents between adopters and user innovators is equal to zero at the 5% level of significance.

Age	**Obs.**	**Mean**	**Median**	**SD**	**Min**	**Max**
Adopter	1,124	23.62	23	6.11	12	51
User innovator	272	22.81	22	5.89	13	42
Total	**1,396**	**23.46**	**23**	**6.08**	**12**	**51**

Educational status: In addition to age we also control for the highest educational status achieved by our respondents. Table 7 presents the distribution of educational levels indicated by the respondents. Dummy variables for the highest educational status achieved by a respondent are included in the regressions and the category "still in school" is treated as reference group.

4 Multivariate analysis

4.1 Model specification

In this Section we present a multivariate analysis of users' pirate behavior linking the share of pirated games $\widetilde{y}_i$ to a vector of independent variables x_i described above and a vector of controls for additional potential determinants of pirate behavior z_i. As point of departure of our multivariate analyses, we estimate the coefficient vectors β and γ in the familiar linear regression model

Table 7: Distribution of highest educational degree achieved. Note: Percentages are reported in parentheses. A χ^2-test rejects the hypotheses that the distribution is equal for adopters and user innovators at the 5% level.

	Adopter	User innovator	Total
Still in School	215	58	273
	(19.58)	(21.89)	(20.03)
High School	366	83	449
	(33.33)	(31.32)	(32.94)
Bachelor	445	104	285
	(40.53)	(39.25)	(20.91)
Master or higher	72	20	92
	(6.55)	(7.55)	(6.75)
Total	1,098	265	1,363
	(100)	(100)	(100)

$$\widetilde{y_i} = x_i'\beta + z_i'\gamma + \epsilon_i \tag{1}$$

with

$$\epsilon_i \sim N(0, \sigma). \tag{2}$$

However, the classical linear regression model as specified in (1) and (2) does not take into account the nature of our dependent variable properly: pirate behavior is a latent variable which is not observable by the econometrician. However, what can be observed is a proxy of the latent variable – the share of games owned by a user which he obtained infringing on copyrights (pirated games). It is important to note that the observed variable is a function of the unbounded underlying latent variable but is – as a share – naturally bounded between 0 and 1. Denoting a user's unobserved inclination to pirate behavior (latent variable) as y_i the observational model can more formally be written as

$$\widetilde{y_i} = \begin{cases} 0 & \text{if} \quad y_i < 0 \\ y_i & \text{if} \quad 0 \leq y_i \leq 1 = 0 \\ 1 & \text{if} \quad y_i > 1. \end{cases} \tag{3}$$

The underlying relation between users' unobserved pirate behavior y_i is defined by

$$y_i = x_i'\beta + z_i'\gamma + \epsilon_i \tag{4}$$

with a distribution of ϵ_i defined in equation 2. In situations described by equations (2), (3) and (4) coefficients estimated in a linear regression model as in (1) and (2) will in general be biased towards zero. The Tobit model, however, provides an estimation procedure taking into account the bounded nature of the observed proxy variable yielding unbiased coefficients estimates. Amemiya (1984) contains a survey of Tobit

models.[17] In the following Subsection we will provide estimation results from both the linear regression model and the Tobit model.

4.2 Results and discussion

In Table 8 we present the results from our multivariate analayses. The left part of the table (columns 1 and 2) contains estimation results from the simple OLS model while the right part of the table (columns 3 and 4) presents the Tobit estimates. Moreover, Table 11 in the appendix contains the cross correlations of the variables used in our regressions.

Overall, almost all of the coefficients are estimated with high precision and carry the expected signs as suggested in the descriptive analysis. Moreover, we find the OLS coefficient estimates to be slightly smaller than the Tobit which is not surprising as the Tobit model takes into account the truncated nature of the observed variable (Amemiya 1984). When discussing the regression results we focus solely on the Tobit estimates in the following as this model better covers the truncated nature of our measure (share of pirated games) of the underlying latent variable (inclination to engage in pirate behavior).

We formulated the expectation that higher perceived benefits from pirate behavior should increase users' tendency to engage in pirate behavior. This hypothesis is tested by including the total number of games owned by a respondent as well as a dummy variable indicating whether the respondent reported that piracy was a 'very important' motivation for him to modify his XBox. Our expectations with regard to benefits from piracy are confirmed by the data as the coefficients of both variables are positive and highly significant across all specifications (see Table 8). In particular, the share of pirated games is almost 20 percentage points higher for respondents who reported that the possibility of running pirated games was a 'very important' motivation for them to hack the XBox. While the magnitude of the coefficient of the total number of games seems to be relatively small it should be taken into account the observed variance in the underlying variable is large. In fact, an increase of the total number of games owned by a standard deviation is associated with an average increase in the share of pirated games by about 11 percentage points everything elso being equal.

In Section 3.3, we also posited a negative relationship between a respondent's general attitude towards the protection of immaterial goods like music or software by copyrights and the degree of pirate behavior he exhibits. In fact, our index of a respondent's attitude towards copyright protection has a highly significant negative influence on a users inclination to engage in pirate behavior. We interpret this finding as a clear indication that personal attitudes towards legal frameworks influence respondents degree of piracy behavior which is in line with the results of previous studies (Eining &

[17]The model specified by equations (2), (3) and (4) can be considered as a type 1 Tobit model according to the classification proposed in Amemiya (1984).

Table 8: Results from linear and Tobit regression models linking the share of pirated games owned by XBox users to observed user characteristics. Note: Standard errors in brackets. * denotes significance level 5%, ** 1%. For the Tobit Models Pseudo-R^2 is reported.

Share of pirated games	Linear Models (1)	Linear Models (2)	Tobit Models (3)	Tobit Models (4)
# of all games owned	0.0014**	0.0014**	0.0016**	0.0016**
	[0.0001]	[0.0001]	[0.0002]	[0.0002]
Piracy "very important"	0.1564**	0.1561**	0.1916**	0.1911**
	[0.0180]	[0.0180]	[0.0224]	[0.0223]
Attitude towards IPR	-0.0874**	-0.0887**	-0.1106**	-0.1123**
	[0.0127]	[0.0127]	[0.0159]	[0.0159]
Community participation	-0.0435**	-0.0239	-0.0614**	-0.0349
	[0.0153]	[0.0185]	[0.0193]	[0.0233]
User Innovator	-0.0412*	0.1171**	-0.0525*	0.0761
	[0.0208]	[0.0170]	[0.0212]	[0.0686]
User Inno. * Particip.		-0.0603$^+$		-0.0831*
		[0.0322]		[0.0410]
Prior Knowledge	0.1178**	0.0524	0.1450**	0.1441**
	[0.0171]	[0.0543]	[0.0263]	[0.0212]
Self modified	-0.0405*	-0.0410*	-0.0487*	-0.0495*
	[0.0177]	[0.0177]	[0.0221]	[0.0220]
Age	0.0164	0.0170	0.0181	0.0188
	[0.0092]	[0.0092]	[0.0115]	[0.0115]
Age squared	-0.0004*	-0.0004*	-0.0004$^+$	-0.0004*
	[0.0002]	[0.0002]	[0.0002]	[0.0002]
High School Degree	0.0427	0.0429	0.0469	0.0471
	[0.0241]	[0.0241]	[0.0300]	[0.0300]
College Degree	0.0779**	0.0778**	0.0903**	0.0902**
	[0.0268]	[0.0267]	[0.0333]	[0.0333]
Master (or higher) Degree	0.0195	0.0167	0.0200	0.0161
	[0.0410]	[0.0410]	[0.0517]	[0.0516]
Constant	0.5588**	0.5296**	0.5916**	0.5516**
	[0.1241]	[0.1249]	[0.1549]	[0.1560]
Observations	1376	1376	1376	1376
R^2/ Pseudo-R^2	0.28	0.28	0.21	0.21

Christensen 1991).

A user's level of activity and participation in an innovation community is expected be inversely related to his inclination to engage in pirate behavior. In column 3 of Table 8 where we do not control for a potential interaction between user innovator characteristics and the level of community activity. In this simple specification we find a highly significant negative relationship between the activity index and the share of pirated games owned by a respondent which conforms with our expectations. The effect is substantial in its magnitude: a one standard deviation increase of the activity-index

reduces the share of pirated games by -6.13%.

Turning to the distinction of user innovators and adopters (which is based on the fact whether a respondent actively developed modifications for the XBox or not) we find that innovators pirate significantly less games than adopters. The estimated coefficient indicates that the share of pirated games is about 5.2% lower than the share of pirated games among mere adopters of outlaw innovations. This finding is line with previous evidence brought forward by Mollick (2004). Once we control for a moderating effect of the level of community participation of innovators by including an interaction term between activity and user innovators we find only the interaction term to be significant. User innovators which are very active in the community are less prone to engage in pirated behavior while the base effect of the user innovator dummy is not significant in this specification. However, this result has to be interpreted with some caution as the correlation between the interaction term and the user innovator dummy is quite large (0.906) which might reduce the precision of the estimation of the two coefficients.

With regard to the demographic variables in the regression we find a negative relationship between age and the tendency to engage in piracy.[18] With regard to the highest educational degree of the respondents we find users who hold a college degree as highest educational degree to be most active in piracy. The remaining categories (high school degree, master of higher) are not significantly different from the reference group (users still in school).

5 Conclusion

The importance of user innovations has been acknowledged widely in the literature (von Hippel 1988, 2005). Recently many authors highlighted the importance of user communities in the process of developing and communicating innovations brought forward by users (Franke & Shah 2003, Hienerth 2006, von Hippel 2005). It has further been argued that not only the users but also manufacturers can profit from innovative activities of a product's users (Jeppesen & Molin 2003, Mayrhofer 2005, Jeppesen & Frederiksen 2006, Prügl & Schreier 2006, Jokisch 2007).

Following Mollick (2004) and Flowers (2008) we focus on situations where users innovations might be harmful to manufacturers when they enable user to bypass security mechanisms in order to engage in pirate behavior. In particular, our analysis of the role of an outlaw innovation community yields interesting insights: On the one hand, participants in these community exhibit pronounced pirate behavior. On the other hand, active participation in the community reduces the degree of pirate behavior.

[18] Note that the effect of the squared age is negative and highly significant while the coefficient of the linear effect is insignificant.

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A Appendix

A.1 Measurement of attitudes towards copyright protection of immaterial goods

We included five items related to a person's attitudes towards copyright protection of immaterial goods in our questionnaire. Participants in the survey were asked to indicate their level of agreement ('strongly disagree', 'disagree', 'neither agree nor disagree', 'agree', 'strongly agree') to the following five statements:

1. Downloading music files from the internet without paying should be punished like theft.
2. It's alright to copy games since I wouldn't have paid for them anyway.
3. I always buy software (instead of copying it) if it fully satisfies my needs.
4. Information goods like software should be free of charge.
5. People who buy software legally are fools that burn their money.

Based on these five items we build an equally weighted index of the five items (weights of 1/5 are applied to each item). This approach seems to be justified as a Principal Component Analysis indicates the existence of one factor with an eigenvalue greater than 1 (see Table 9). Cronbach's alpha (Scale reliability coefficient) for this index is 0.61.

Table 9: Factor loadings of items related to respondents attitude towards copyright protection of immaterial goods derived from a Principal Components Analysis. Note: We only report factor loadings with regard to factors with eigenvalues larger than 1. The eigenvalue of the identified factor is 1.967.

Variable	**Factorloadings**
Item 1: Downloading music files ...	0.403
Item 2: It's alright to copy ...	-0.468
Item 3: I always buy software ...	-0.453
Item 4: Information goods like software ...	0.386
Item 5: People who buy software ...	-0.513

A.2 Measurement of community activity

We included six items relating to different forms of community activity in our questionnaire. Participants in the survey were asked to indicate their level of agreement ('never', 'once a month', 'once a week', 'several times a week', 'daily') to the following five statements:

"Xbox-linux.org provides comprehensive information for Xbox users. Please indicate how often you..."

1. visit xbox-scene.com.
2. read the discussions on xboxscene.com
3. participate in discussions on xboxscene.com.
4. initiated discussions on xboxscene. com.
5. are looking for information to download software on xbox-scene.com.
6. are looking for tutorials on xboxscene. com.

Based on these six items we build an equally weighted index of the items (weights of 1/6 are applied to each item). This approach seems to be justified as a Principal Component Analysis indicates the existence of one factor with an eigenvalue greater than 1 (see Table 9). Cronbach's alpha (Scale reliability coefficient) for this index is 0.91.

Table 10: Factor loadings of items related to activity in XBOX-Scene.com derived from a Principal Components Analysis. Note that we only report factor loadings with regard to factors with eigenvalues larger than 1.

Variable	**Factorloadings**
Item 1: visit xbox-scene.com	0.4107
Item 2: read the discussions	0.4246
Item 3: participate in discussions	0.4087
Item 4: initiated discussions	0.3907
Item 5: download software	0.4133
Item 6: looking for tutorials	0.4007

A.3 Correlation table

Table 11: Cross-correlation table of the variables used in our multivariate analyses.

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	Share pirated games	1.000													
(2)	Tot. number of games	0.327	1.000												
(3)	Running pirated games very important	0.337	0.140	1.000											
(4)	Attitude towards copyrights	-0.305	-0.098	-0.392	1.000										
(5)	Community participation	-0.085	-0.015	-0.053	-0.039	1.000									
(6)	User innovator (0/1)	-0.069	0.081	-0.091	0.042	0.184	1.000								
(7)	(5) * (6)	-0.086	0.081	-0.085	0.007	0.403	0.905	1.000							
(8)	Knowledge of hackability (0/1)	0.192	0.013	0.022	-0.079	0.064	-0.009	0.001	1.000						
(9)	Modification performed (0/1)	-0.082	0.039	-0.037	0.046	0.080	0.095	0.097	-0.044	1.000					
(10)	Age	0.012	0.219	-0.120	0.204	-0.034	-0.052	-0.058	0.111	-0.038	1.000				
(11)	Age (squared)	-0.004	0.204	-0.105	0.195	-0.019	-0.049	-0.053	0.097	-0.034	0.986	1.000			
(12)	Highest degree: high school	0.040	0.031	0.092	-0.063	-0.059	-0.017	-0.023	-0.038	0.004	-0.095	-0.093	1.000		
(13)	Highest degree: bachelor	0.055	0.040	-0.105	0.109	-0.017	-0.011	-0.010	0.077	-0.054	0.329	0.277	-0.554	1.000	
(14)	Highest degree: master or higher	-0.037	0.060	-0.057	0.055	0.113	0.015	0.026	0.062	0.013	0.249	0.246	-0.183	-0.214	1.000