Group Size and Incentive to Contribute: A Natural Experiment at Chinese Wikipedia*

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Abstract

The literature of private provision of public goods suggests that incentive to contribute is inversely related to group size. This paper empirically tests this relationship using field data from Chinese Wikipedia, an online encyclopedia based entirely on user contributions. The blocking of Wikipedia in mainland China has exogenously reduced the group size of contributors. We exploit this reduction in group size to examine whether individual contributions increase after the block, as predicted in the literature. Our result indicates the opposite: individual contributions of contributors outside mainland China decrease by 41.4% on average as a consequence of the block. We attribute the cause to social effects: a contributor receives social benefits that increase in both the amount of her contributions and group size, and the shrinking group size weakens these social benefits. Consistent with our explanation, we find that the more a contributor values social benefits, the greater the reduction in her contributions after the block. A series of robustness checks appear to support our findings.

Key words: incentive to contribute; group size; public goods; social effects; Wikipedia; Internet censorship

1 Introduction

A fundamental question in the private provision of public goods concerns the relationship between group size and incentive to contribute. The major focus of the literature has been the "crowding out" hypothesis: when the population grows, individual contribution level declines (e.g., Olson 1965; Andreoni 1988). The intuition is that individuals treat others' contributions as substitutes to their own. Consequently, as group size increases, they are more likely to free ride.

We empirically examine the causal effect of changes in group size on individual contributions. Our identification hinges on an exogenous reduction in group size at Chinese Wikipedia, the Chinese language version of an online encyclopedia that relies entirely on voluntary contribution. Contributors to Chinese Wikipedia are composed of Chinese-speaking people in mainland China, Taiwan, Hong Kong, Singapore and other regions in the world. We exploit the block to Chinese Wikipedia in mainland China in October 2005. While contributors outside mainland China were not affected, mainland Chinese could not use or contribute to Chinese Wikipedia after the block.

We empirically test whether the reduction in group size leads to increases in individual contributions, as predicted in the literature. Our results indicate the opposite: individual contributions of unaffected contributors decrease by 41.4% on average as a result of the block. We attribute the cause to social effects: a contributor receives social benefits that increase in both the amount of her contributions and group size, and the shrinking group size weakens these social benefits. We present a simple model to illustrate how social effects and group size affect individual incentive to contribute. Consistent with our explanation, we find that the more a contributor values social benefits, the greater the reduction in her contributions after the block.

The relationship between group size and incentive to contribute has been examined extensively in the literature on private provision of public goods. Theoretical models tend to find support for the "crowding out" hypothesis. Andreoni (1988) and Fries et al. (1991) show in the context of continuous public goods that as group size increases to infinity, individual contribution level falls to zero. Palfrey and Rosenthal (1984) and Hindriks and Pancs (2002) analyze discrete public goods[1] and obtain the same result. As Andreoni (1988, 1989) points out, these theoretical results that increases in group sizes completely crowd out individual contributions make the Red Cross, the

[1] That is, the public good is provided only when a sufficient number of contributions are made.

Salvation Army, and American Public Broadcasting logical impossibilities and thus have limited predictive power.

Scholars have introduced warm glow to help reconcile the inconsistency between the theoretical literature and empirical observations (e.g., Andreoni 1989; Konow 2006). In these models, contributors receive not only utility from total provision of the public good, but also a private benefit or warm glow, such as moral satisfaction and joy of giving. Because of warm glow, a contributor no longer treats others' contributions as perfect substitute of her own. The crowding out from the increase in group size thus becomes incomplete. As Ribar and Wilhelm (2002) show, as group size expands, each individual's marginal utility from the actual provision of the public good diminishes. In the limit, their incentives to contribute are solely determined by "warm glow."

Different from warm glow, with social effects, the private benefit a contributor receives increases in both the amount of her contributions and the size of the group. Depending on the context, such social effects could also be referred to as "social norms," "social contagion," "peer influences," "social interactions," "reciprocity," "interdependent preferences" (Manski 1993). The idea that contributors receive social benefits has been suggested numerous times in the literature (e.g., Andreoni and Scholz 1998; Becker 1974; van Dijk and van Winden 1997; Rege 2004; Rege and Telle 2004; Carman 2006). A number of recent studies on open source communities and online reviews also find that individual contributor indeed derives utility from helping others and gaining reputation, and such utility may grow with the number of beneficiaries of her contributions (e.g., Lerner and Tirole 2002; Lakhani and von Hippel 2003; Dellarocas and Narayan 2006; Rashid et al. 2006; Ren et al. forthcoming).

In our study, we incorporate social effects into individual contributor's utility function to examine how contributors' contributions change with group size. For a given level of contribution, the larger the group, the greater marginal social benefits a contributor derives. We show that explicitly incorporating social effects may overturn the inverse relationship between group size and incentives to contribute found in prior theoretical models.

Our research contributes to the empirical literature by providing evidence of causal effect of group size on contributors' contribution levels. The majority of the existing literature is based on experimental data. In general, these experiments find increased free-riding behavior in larger groups (e.g., Sweeney 1973; Chamberlin 1978), although some of the studies suggest that group

size effect could be weak (e.g., Marwell and Ames 1979; Chamberlin 1978). One exception is Isaac et al. (1994), which finds that groups of 40 and 100 subjects provide the good more efficiently than groups of 4 and 10. In their study, however, the public good is divided among participants. As a result, an increase in group size reduces the benefit of the public good to each participant. Laboratory studies on this topic are necessarily handicapped because in comparison with the group sizes we often find in real world, groups used in the experiments are of very small sizes.

A couple of studies have used field data to test the group size effect. Goetze et al. (1993) examine contributions to public television stations and find that average contributions per contributor decrease with group size. Brunner (1998) studies contributions to public radio stations and finds that the proportion of listeners contributing to public radio decreases as the number of listeners increases. In addition, he finds that as group size increases, average contributions per contributor remain constant. Our empirical study differs from these studies in two aspects. First, while the two studies use aggregate data and divide them by the number of contributors, we measure changes in contributions at the individual level and examine heterogeneity among individual contributors. Second, we exploit an exogenous change of group size to establish the causal relationship between group size and incentive to contribute. Many factors could change group size and incentives to contribute at the same time. Thus the relationships found in prior studies could be spurious.

The rest of the paper is organized as follows. Section 2 provides a simple model to demonstrate that with social effects, contributors' contribution levels may increase with group size under certain conditions. Section 3 provides background of Chinese Wikipedia and blocks and unblocks of Chinese Wikipedia in mainland China. Section 4 presents the empirical results. Section 5 conducts various robustness checks. Section 6 concludes.

2 A Simple Model of Private Provision of Public Goods with Social Effects

There are M different types of people in an economy with one public good. Let T be the total amount of disposable time for each person. We follow the approach in Fries et al. (1991) to model an increase in the size of the economy. We assume that there are mass N individuals of each type and call N the size of the economy, or the group size.

Let w_{ij} denote the amount of time an individual j, $1 \leq j \leq N$, of type i, $1 \leq i \leq M$, spends on contributing to the public good. The individual spends the remaining time, $v_{ij} = T - w_{ij}$, on leisure activities.

Individuals of different types have different values on the social benefit they receive from their contribution. Let $S_i(w_{ij}, N)$ denote the social benefit contributor j of type i receives from contributing to the public good. $S_i(\cdot, \cdot)$ is an increasing and concave function of w_{ij}. An important distinction between social effects and warm glow is that with social effects, the marginal benefit from contributing, $\frac{\partial S_i}{\partial w_{ij}}$, increases with group size, whereas with warm glow, it does not change with group size. We refer to the rate of this change, $\frac{\partial^2 S_i}{\partial w_{ij} \partial N}$, as the strength of social effects.

Let $W = \sum_{i=1}^{M} \sum_{j=1}^{N} w_{ij}$ be the total amount of time devoted to the public good. We assume that each contributor produces one unit of public good with one unit of time. Hence, W is also the total amount of the public good produced. Let $U(v_{ij}, W)$ be the utility a contributor receives from her leisure activities and from the use of the public good.[2] $U(v_{ij}, W)$ is an increasing and concave function in both v_{ij} and W. In addition, we assume the marginal utility from private leisure activities and the public good is independent. That is, if we denote U_v and U_W as the partial derivatives of U with respect to the first and second parameters and U_{vW} as their cross-partial derivative, we have $U_{vW} = 0$.

For an individual j of type i, she allocates her total disposable time to maximize the following utility:

$$\max_{v_{ij}, w_{ij}} U(v_{ij}, W) + S_i(w_{ij}, N) \tag{1}$$

$$s.t.\ v_{ij} + w_{ij} \leq T,\ w_{ij} \geq 0\ and\ v_{ij} \geq 0$$

Under the Nash assumption, each individual takes other people's contribution as given when solving for her own optimal time allocation. We thus re-write the utility function as

$$\max_{w_{ij}} U(T - w_{ij}, w_{ij} + \sum_{h=1, h \neq j}^{N} w_{ih} + \sum_{k=1, k \neq i}^{M} \sum_{t=1}^{N} w_{kt}) + S_i(w_{ij}, N) \tag{2}$$

We focus on the symmetric equilibrium in which individuals of the same type contribute the

[2]Beginning with Bergstrom et al. (1986), studies on private provision of public goods (e.g. Andreoni 1988; Falkinger et al. 2000) have repeatedly adopted similar utility functions.

same amount of time. We also assume that for some types of contributors, their solutions to the maximization problem is interior.[3] Without loss of generality, we assume that the solution is interior for contributors of type i. We take the first-order condition with respect to w_{ij} and obtain:

$$-U_v(T - w_i^*, \cdot) + U_W(\cdot, Nw_i^* + N \sum_{k=1,k\neq i}^{M} w_k^*) + \frac{\partial S_i(w_i^*, N)}{\partial w_i} = 0, \tag{3}$$

where w_i^* and w_k^* are equilibrium amount of contribution for individual of type i and type k.

Our objective is to understand how the equilibrium contribution level, w_i^*, changes with group size, N. We first consider the impact of group size on the amount of contribution when the strength of social effects is zero, i.e., $\frac{\partial^2 S_i(w_i^*,N)}{\partial w_i \partial N} = 0$.

Denote the left hand side of equation (3) as H. Assume N is a big number so that we treat it as a continuous variable. By the implicit function theorem, we have

$$\begin{aligned} \frac{dw_i^*}{dN} &= -\frac{\partial H/\partial N}{\partial H/\partial w_i^*} \\ &= -\frac{U_{WW} \cdot (w_{ij}^* + \sum_{k=1,k\neq i}^{M} w_k^*) + \frac{\partial^2 S_i}{\partial w_i \partial N}}{U_{vv} + N \cdot U_{WW} + S_{i,ww}} \end{aligned} \tag{4}$$

We know that $U_{vv} < 0$, $U_{WW} < 0$, $S_{i,ww} < 0$ and $(w_{ij}^* + \sum_{k=1,k\neq i}^{M} w_k^*) = W/M > 0$. Hence, when $\frac{\partial^2 S_i}{\partial w_i \partial N} = 0$, we have $\frac{dw_i^*}{dN} < 0$. We summarize the result in the following proposition:

Proposition 1. *When the strength of social effects is zero, i.e., $\frac{\partial^2 S_i}{\partial w_i \partial N} = 0$, the equilibrium amount of time each individual allocates to the public good decreases with the group size: $\frac{dw_i^*}{dN} < 0$.*

Proposition 1 is essentially a restatement of the familiar result that without social effects, individual incentive to contribute decreases with group size. The result is intuitive. Without social effects, an individual of type i will contribute the level when the marginal benefit from contributing to the public good U_W equals the marginal benefit from the leisure time U_v. When N increases, the marginal benefit from contributing to the public good decreases. Hence, the optimal response is to reduce the contribution level so that U_w continues to equal U_v when N increases. We thus observe more free-riding as N increases.

[3] For example, this assumption will hold when the marginal benefit from social effects is greater than the marginal benefit from the private consumption when the contribution is small but drops faster as the contribution increases.

We now consider the case with positive social effects, i.e., $\frac{\partial^2 S_i}{\partial w_i \partial N} > 0$. It is easy to conclude from equation (4) that when $\frac{\partial^2 S_i}{\partial w_{ij} \partial N} > -U_{WW}(W/M)$, we have $\frac{dw_i^*}{dN} > 0$; otherwise, we have $\frac{dw_i^*}{dN} < 0$. Notice that the threshold $-U_{WW}(W/M)$ is the same for every person. Hence, for contributors whose contribution levels are in $(0, T)$, when N increases, those whose strength of social effects is above this threshold increase their contribution levels and the rest will decrease their contribution levels. We summarize the result in the next proposition:

Proposition 2. *With positive strength of social effects, i.e., $\frac{\partial^2 S_i}{\partial w_i \partial N} > 0$, the equilibrium amount of time each individual allocates to the public good increases if the strength of social effects is above a certain threshold and decreases otherwise.*

Proposition 2 suggests a tension between the incentive to free ride and the desire to enjoy increased marginal social benefits when group size increases. It indicates that when marginal social benefit from contributing increases sufficiently with group size, individuals' incentive to contribute may actually increase with the group size.

3 Background

3.1 Wikipedia

Wikipedia is a Web-based free encyclopedia project operated by the Wikimedia Foundation, a nonprofit charitable organization. It was launched in January 2001. Its goal is to "give every single person in the world free access to the sum of all human knowledge."[4] Wikipedia articles have been written collaboratively by volunteers around the world and can be edited by anyone with access to the Internet. The online encyclopedia contains more than 10 million articles in 264 languages and is the fourth most visited website in the world. The English-language edition, the first and largest edition of Wikipedia, has more than 2.6 million articles and receives about 186 million page hits per day.[5]

In addition to Wikipedia, the Wikimedia Foundation operates several online wiki-based projects including a multi-language dictionary and thesaurus named Wiktionary, an encyclopedia of quo-

[4] `http://en.wikipedia.org/wiki/User:Jimbo_Wales`, accessed May 2008.

[5] `http://en.wikipedia.org/wiki/Special:Statistics`, and `http://wikistics.falsikon.de/latest/`, accessed May 2008.

tations named Wikiquote, a repository of source texts in any language named Wikisource, and a collection of e-book texts for students named Wikibooks.

3.2 Chinese Wikipedia

Chinese Wikipedia started in October 2002, and is the Chinese language edition of Wikipedia. Due to political concerns, the Chinese government has established the "great firewall" to censor the access of mainland Chinese to various information sources, among which are all Wikipedia's sites.[6] Access to Chinese Wikipedia has been blocked and unblocked in mainland China six times.[7] The first block took place on June 2, 2004. All Wikipedia sites[8] were blocked in mainland China. In response to the block, two administrators of the Chinese Wikipedia site, 'Shizhao' and 'Mountain,' contacted their respective Internet Service Providers (ISPs), and drafted an appeal, which was submitted on June 15, 2004. During the period between June 17 and June 21, 2004, all Wikipedia sites were unblocked.

The second block, which lasted from September 23 to September 27, 2004, was not universal. While some users in mainland China reported that during this period access to Wikipedia had been erratic or unavailable, many users in mainland China were never affected.

The third block began on October 19, 2005. Shizhao once again submitted an appeal to his ISP on October 21. Given the experience with the first two blocks, many people expected the block to be lifted soon. The appeal received no response. On the morning of October 31, 2005, surprisingly, contributors from mainland China began to report that they could access Wikipedia. It turned out that this "unblocking" was linked to a server upgrade in the Korean server cluster. A change of the Internet Protocol (IP) address of the Wikipedia site for users in China circumvented the block. Within a few hours, Wikipedia was once again blocked. The prompt block on October 31 made it abundantly clear to the Chinese Wikipedia community that the block was going to be longer than expected. Since then, no more efforts of appeal have been made.

Nearly a year later, the block was partially lifted. Beginning from October 10, 2006, some parts of mainland China could access Wikipedia. On November 10, 2006, Chinese Wikipedia appeared

[6] Deibert (2002) and Zittrain and Edelman (2003) give a detailed introduction to this issue.

[7] The latest information about the blocks can be found at `http://en.wikipedia.org/wiki/Blocking_of_Wikipedia_in_mainland_China`, accessed May 2008.

[8] In addition to Wikipedia in various languages, the Wikimedia Foundation manages other sites such as a multi-language dictionary and thesaurus named Wiktionary and an encyclopedia of quotations named Wikiquote.

to have been fully unblocked but was reblocked on November 17.

The fifth unblock took place in July 2007. On June 15, 2007, the block to Wikipedia sites was lifted, with the exception of several sensitive articles and Chinese Wikipedia. On July 25, 2007, Chinese Wikipedia was unblocked as well, only to be blocked again after several hours.

On April 2, 2008, all Wikipedia sites except the Chinese Wikipedia site and web pages with politically sensitive content were unblocked. The move came two days after the International Olympic Committee (IOC) warned China that it wanted the Internet freely accessible during the Olympic Summer Games. Starting from July 3, 2008, China has stopped restricting access to Chinese Wikipedia in some parts of the country. The unblock was extended to the whole China around one week before the opening of the Olympic Games. Many believed that the lift of the ban was because of Beijing's obligation under the "host city contract" with the IOC to permit unrestricted Internet access during the games.

Chinese Wikipedia offers an ideal empirical setting to study the relationship between group size and incentive to contribute for several reasons. First, individual contribution level can be easily measured in Wikipedia. Wikipedia keeps the complete editing history of all articles, and each edit can be traced to an ID that uniquely identifies the contributor. As a result, we are able to accurately measure the contributions from each contributor over time.

Second, the blocks of Chinese Wikipedia present an easy way to address the endogeneity problem. Changes in individual contributions could correlate with group size for various reasons. Merely associating group size with the amount of contributions may be misleading in assessing their relationship. For example, individual contributors often contribute less over time, while the number of contributors at Wikipedia in general increases over time. While this observation is consistent with the crowding-out hypothesis in the literature, it might be a result of the contributors having less to contribute over time, or might simply be a case of their slacking off after a "honeymoon" period.

To establish a causal relationship, it is critical to look for factors that change group size exogenously. The blocks provide natural experiments to examine the impact of group size. The blocks are exogenous as for each block there was no warning beforehand nor explanations afterwards. As contributors outside mainland China were unaffected, we could examine changes in their contribution levels and study how their incentives to contribute change as a result of the change in group size.

Third, contributors at Wikipedia are motivated mostly by altruism (Nov forthcoming). In many other public good provision circumstances such as open source software projects, contributors may be motivated by monetary payment and potential career advancement (see, for example, Lerner and Tirole 2002), and their incentives to contribute are difficult to study.

Finally, Wikipedia is widely regarded as a promising model for knowledge sharing (e.g., Greenstein and Devereux 2006; Lakhani and McAfee 2007; Wagner and Majchrzak 2007). Many other online communities and firms are starting to adopt similar models to facilitate collaborations. Our results thus have important implications for future knowledge-sharing communities.

Our empirical analysis focuses on the third block which took place in October 2005 and lasted for nearly one year. Figure 1 shows the number of new contributors in Chinese Wikipedia over time. We find that before this block, the number of contributors grew exponentially over time. The number dropped significantly as a result of the block. Shortly after the block, the number continued to grow at an even faster rate, most likely due to the great deal of publicity Chinese Wikipedia received as a result of the block. We choose to focus on the third block as it is the longest block among the five blocks. In the other five instances, blocking and unblocking either happened within several days or took place together with other confounding events (e.g., Olympic Games). Their impact on individual contribution is difficult to measure. In addition, after the third block, many people believed that the ban was going to be permanent and the unblocks were due to upgrades to the Great Firewall System. Given these expectations, contributors may not adjust their contribution levels during the temporary changes in group size.

The third block was also well publicized. Figure 2 shows the search volume index for the term "Chinese Wikipedia" from Google. The search volume increased substantially right after the third block. In response to this block, the home page of Chinese Wikipedia added a link at the top directing any user from mainland China to a status page on October 20, 2005. Unaffected contributors could easily learn about the block. This frees us from a concern in some of previous studies that individual contribution levels do not change because contributors may be unaware of the changes in the environment (Konow 2006). We empirically investigate the changes in contribution levels of these unaffected contributors before October 19, 2005 and after October 31, 2005.

4 Empirical Analysis

4.1 Data

We obtain our data set from the Chinese Wikipedia Web site (`http://zh.wikipedia.org/`). This data set contains the full text of all the articles and their complete editing histories. There were 196,130 articles posted between October 2002 and February 2007. To study the impact of the block, we focus on contribution of unaffected contributors four weeks before October 19, 2005, and four weeks after October 31, 2005. We choose this relatively short time window because the group size increased again after the block. Hence, results from a big time window may not accurately reflect the impact of reduction in group size.[9] The 8-week time window also allows us to avoid potential seasonal effects from holidays at the end of the year. During this 8-week period of time, 9,048 new articles were initiated.[10] A total of 53,519 revisions were made on all Chinese Wikipedia articles. The total number of additions and deletions measured in characters[11] are 10,436,966 and 4,321,112, respectively.

Contributors are identified by their IDs if they have registered. Otherwise, they are identified by their network IP addresses at the time of connection. As the same IP address can map to multiple contributors and a contributor may not always use the same IP address when contributing, we focus on registered contributors in our analysis. Since administrators and robots have different editing patterns, we also exclude them from the analysis. For each article, we record the revision time, contributor ID, and the number of characters added and deleted in each revision. We then use this information to generate contribution history of each contributor in each week.

In addition to article pages on Wikipedia, each contributor can have her own user page or user-talk page. Many contributors add information about themselves such as contact information, photographs, and information about their areas of expertise and interest on their user pages or user-talk pages. Some contributors also use these pages to discuss issues related to Wikipedia articles with others. Generally these user pages and user-talk pages, like Wikipedia articles, can be

[9] Our results, however, are qualitatively unchanged if we study whole time period.

[10] We do not consider the contributions made during the period between October 19, 2005 and October 31, 2005 for two reasons. First, the block is not complete in all areas until October 31. Second, we expect a lag between the block and the possible change in behavior of the unaffected contributors.

[11] In Chinese, characters form the basic unit of meaning. Not all characters can stand alone as a word but most Chinese words are formed by two or three characters.

modified by anyone. We also obtain the contribution history of each contributor in user pages and user-talk pages.

4.2 Identifying Unaffected Contributors

We first need to identify the contributors who are unaffected by the block. Wikipedia reveals neither geographic information about individual contributors nor network IP addresses of registered contributors. As a result, we rely on two information sources to identify these unaffected contributors.

First, we use the contribution history of each contributor to infer whether she was affected by the block. We consider a contributor as unaffected if she joins Chinese Wikipedia before the beginning of the block (i.e., October 19, 2005) and contributes at least once during any of the blocked periods. 6,062 contributors joined Wikipedia before the block and 1,623 of them are classified as unaffected contributors.

Second, we rely on the encoding of the characters entered by the contributors. Chinese characters are encoded in two major standards in order to be correctly displayed. Table 1 lists the standards used in different regions. Due to historical reasons, Taiwan, Hong Kong, and Macau adopted Traditional Chinese characters (encoded in BIG5) while those from mainland China, Singapore, and Malaysia use Simplified Chinese characters (encoded in GB2312) to edit articles.[12] Through analyzing the encoding used by each contributor, we can identify whether a contributor uses Simplified or Traditional Chinese. Those who use Traditional Chinese to edit articles are very likely to be outside mainland China and thus are unaffected by the block. We analyze characters added by each contributor. Some contributors add characters in both encodings, most likely because they copy and paste contents from other sites whose characters are encoded differently from the ones they are using. Hence, we consider a contributor as unaffected if more than fifty percent of her additions are in Traditional Chinese. 1,207 contributors are identified as users of Traditional Chinese. Among them, 118 joined Chinese Wikipedia before the block. These numbers are smaller than the ones we obtain from the first approach as many unaffected contributors use Simplified

[12] See `http://en.wikipedia.org/wiki/Big5` and `http://en.wikipedia.org/wiki/GB2312`, accessed May 2008. While it is common that Simplified Chinese is used outside of mainland China, it is extremely rare for Traditional Chinese to be used inside mainland China.

Chinese.[13]

We then combine the two lists of unaffected contributors. In total, we have 1,707 unaffected contributors who joined Chinese Wikipedia before the block. It is possible that our classification scheme excludes those unaffected contributors who use Simplified Chinese and made no contribution during the blocked periods. Our results would be strengthened had these contributors been included.

4.3 Summary Statistics

Table 2 reports summary statistics for contributions by each contributor. We use the number of characters added, the number of characters deleted, and the total number of characters added and deleted as measures for individual contributions. We consider addition and deletion as different forms of editing as the amount of effort involved may be different. For each contributor, we compute her level of contributions. We conduct paired t-tests to compare contribution levels before and after the block. In Panel A, we report contributions from both affected and unaffected contributors. In Panel B, we only report results for unaffected contributors. We find significant declines in all measures of individual contributions after the block.

4.4 Regression Analysis

We proceed to test the change in contributions in a regression framework for each individual contributor. We first examine the following specification:

$$Contributions_{it} = \beta_0 + \beta_1 AfterBlock_t + ControlVars_{it} + \epsilon_{it}, \tag{5}$$

where i indexes the contributors and t indexes the weeks. The dependent variable, $Contributions_{it}$, is the weekly contributions of each unaffected contributor to Wikipedia articles.

We use the logarithms of the weekly total characters added, deleted and their sums as measures for individual contributions.[14] $AfterBlock_t$ is a dummy which equals 1 if the time period is after the block and 0 otherwise. We also include age, measured as the number of weeks since the contributor

[13] Indeed, Google reports that most searches for "Chinese Wikipedia" come from users in Singapore and Malaysia. `http://www.google.com/trends?q=chinese+wikipedia`, accessed November 2008.

[14] We add 1 to these measures before taking logarithms as some numbers can be zero.

joined Wikipedia, as a control variable, and the square of age to control for possible curvilinear effects.

Table 3 reports our regression results. In Model 1, we use the total number of characters added and deleted as the dependent variable and only include $AfterBlock_t$ as the independent variable. In Model 2 and 3, we include Age and then Age^2 as the control variables. In Model 4 and 5, we use the number of characters added, and the number of characters deleted as the dependent variables. We then repeat the analysis controlling for individual fixed effects in Models 6, 7 and 8. All results show the same pattern: while individual contribution level in general decreases at a decreasing rate with age, the block has significantly reduced contribution level. In addition, the number of characters added drops more than the number of characters deleted. A back-of-the-envelope calculation based on coefficients in Model 6 suggests that individual contributions dropped by 41.4% as a result of the block (Halvorsen and Palmquist 1980; Kennedy 1981).

We next turn to examine the impact of social effects. Our theoretical analysis shows that contributors who derive more social benefits from contributing are more likely to decrease their contributions as group size decreases. We use several approaches to identify contributors among these unaffected ones who are likely to derive great social benefits from contributing.

We first consider contributors' participation in user-pages and user-talk pages. Active participation in these pages suggests that these contributors are more likely to desire a high level social utility from contributing to Wikipedia. Therefore, if social effects (e.g., social interactions) provide important motivation for contribution, we expect these contributors with greater social participation to be affected more by the block. We thus compute the number of characters added and deleted by each unaffected contributor in her user pages and user-talk pages before the block. We consider the following differences-in-differences specification:

$$\begin{aligned} Contributions_{it} &= \beta_0 + \beta_1 AfterBlock_t + \beta_2 SocialParticipation_i \times AfterBlock_t \\ &\quad + \beta_3 SocialParticipation_i + ControlVars_{it} + \epsilon_{it}, \end{aligned}$$

where $SocialParticipation_i$ is the logarithm of the sum of total addition and total deletion in user pages or user-talk pages by contributor i before the block.

We report the results in Table 4. The significant positive coefficients of $SocialParticipation_i$

indicate that in general, contributors deriving more social utility contribute more. The negative coefficients of the interaction variable suggest that these contributors are affected significantly more by the block.

One disadvantage of this measure is that more than 85% of contributors do not have user pages or user-talk pages. To better capture the heterogeneity of all contributors, we construct an alternative measure using the fact that contributors who care more about obtaining social benefits may self-select to contribute more frequently to popular articles, and hence they are likely to have large collaboration networks. For each contributor, we measure the number of collaborators per week for each contributor by counting the total number of collaborators in all articles she contributed to before the block and dividing this value by the number of weeks she has been with Wikipedia before the block. Figure 3 shows the distribution of the number of collaborators per week across all contributors. It suggests that for the majority of contributors, their average collaboration networks are small. We then construct a new measure, $CollaborationNetworkSize_i$, by taking the logarithm of the number of collaborators per week. We repeat the differences-in-differences analysis above after replacing $SocialParticipation_i$ with $CollaborationNetworkSize_i$:

$$\begin{aligned} Contributions_{it} &= \beta_0 + \beta_1 AfterBlock_t + \beta_2 CollaborationNetworkSize_i \times AfterBlock_t \\ &\quad + \beta_3 CollaborationNetworkSize_i + ControlVars_{it} + \epsilon_{it} \end{aligned}$$

We report the results in Table 5. We find that contributors with larger collaboration networks decrease their contributions more than those with smaller networks. Interestingly, for contributors with small collaboration networks (i.e., they have low values of $CollaborationNetworkSize_i$), their contributions even increase after the block. The results suggest that for these contributors, free-riding incentives dominate social effects.

Finally, we use the encodings of the Chinese characters contributors use. Unaffected contributors who use Simplified Chinese are more likely to have stronger social ties with mainland Chinese and thus are more likely to care about the visibility of their contributions in mainland China and their interactions with contributors from mainland China. Thus, we expect the blocks in mainland China to reduce their incentives to contribute considerably. Similarly, contributors using Traditional Chinese are likely to come from regions outside mainland China. We thus expect that the changes

in the marginal benefits from contributions for the users of Traditional Chinese to be smaller. Hence, we expect their contributions to decrease less after the block. We construct a new dummy variable, $TraditionalChineseUser_i$, which is 1 if contributor i is identified as a user of Traditional Chinese and 0 otherwise. We employ a similar specification using this new measure:

$$\begin{aligned} Contributions_{it} &= \beta_0 + \beta_1 AfterBlock_t + \beta_2 TraditionalChineseUser_i \times AfterBlock_t \\ &\quad + \beta_3 TraditionalChineseUser_i + ControlVars_{it} + \epsilon_{it} \end{aligned}$$

We report the regression results in the Panel A of Table 6. In Model 1-3, we employ OLS specifications for the three different dependent variables. We then repeat the analysis using fixed effects (the variable $TraditionalChineseUser_i$ drops due to collinearity). We find that while users of Traditional Chinese contribute less on average, their contribution levels decrease much less than users of Simplified Chinese. Based on the estimates in Panel A, we compute the effect of the block on users of Traditional Chinese in Panel B. We find that while the coefficients for contributors using Traditional Chinese are negative in all models, they are not significant. The result suggests that for these contributors, changes in free-riding incentives offset changes in social effects.

Overall, our regression results provide support that social effects play an significant role in contributors' incentives to contribute.

5 Robustness Checks

5.1 Seasonality

A natural concern is whether the results above are a consequence of time-specific effects. It could be that contributors contribute less in November than in September and early October in any year. We examine contributions during the same periods in these two years and find no decline in contributions. In fact, contributions in 2004 increased significantly. The result is consistent with the rapid growth in the number of new contributors during this period. We then replicate the regression analysis for these time periods in years 2003 and 2004.[15] We find that while contributors who value social benefits more contribute more during these periods, we detect no significant difference in

[15] Regression results for robustness checks are not reported here but are available upon request.

their contributions before October 19 and after October 31 in 2003 and 2004.

5.2 Controversial Articles

We are also concerned that the decrease in contributions may result from less disagreement in editing after the block. Contributors in mainland China may hold different political views from those in other regions such as Taiwan.[16] After the block, we would expect to see less disagreement in editing Wikipedia articles and hence less editing. We conduct two tests. First, we focus our analysis on creation of new articles. If the decrease is caused entirely by less disagreement rather than social factors, we would expect no decline in the level of effort in creating new articles.[17] We count the number of characters in each new article. We repeat the regression analysis, this time using the logarithm of weekly contributions in new articles by each contributor as the dependent variable. We find that after the block contributors create fewer new articles, and the decrease is mostly associated with contributors who care more about social benefits.

In the second test, we examine category information for each article. When editing articles, a contributor can map these articles to a list of categories in the database. New categories can also be easily created. For example, an article about "auction theory" would be mapped to such categories as "applied mathematics," "economics and finance," and "game theory." We compile a list of 31,871 categories from all articles, and manually go through the list.[18] In the end, we identify 2,500 categories as contentious categories. We then exclude contributions to articles in these categories and repeat the analysis. The regression results show significant declines in all measures of individual contributions.

5.3 Fewer New Articles for Revision

Our third concern is that the decrease is caused by fewer new articles created. As fewer new articles are created after the block, contributors may have less content to improve. We re-compute

[16] Political sensitive articles are often edited more frequently. For example, the six most edited articles as reported by Wikipedia are Republic of China, China, People's Republic of China, Mao Zedong, Chiang Kai-shek, and Hong Kong.

[17] In fact, the level of effort could increase since contributors could spend more time creating articles after the block.

[18] The complete list of categories can be found at `http://stats.wikimedia.org/EN/CategoryOverview_ZH_Complete.htm`, accessed May 2008.

individual contributions, this time only including the contributions to articles created before the block. We repeat the analysis and obtain similar results.

5.4 Proxy Server

Finally, technically-adept contributors in mainland China might use proxy servers to circumvent the block. As proxy servers are slow, they might contribute less than before. Our classification scheme would classify them as unaffected contributors. As a result, we may observe a decrease in their contribution levels. This concern is alleviated by a Wikipedia policy that prevents contributors from editing using open and anonymous proxies.[19] In addition, the Wikipedia administrators forbid open proxies in a way such that even registered contributors cannot use open proxies to edit articles. It is, however, still possible that not all open proxies are blocked and some users may use closed proxy servers to access Wikipedia.[20]

Contributors who use closed proxy servers have to access their friends' computers outside mainland China in order to edit articles at Chinese Wikipedia. Given the complexity involved in setting up and getting access to closed proxy servers, we expect those who use closed proxy servers to be dedicated and technically-adept Wikipedia contributors. Hence, these contributors are likely to contribute significantly more than other contributors before the block and are likely to contribute to articles related to technology. We conduct our robustness check by removing contributors whose average weekly contributions are more than four standard deviations above the mean before the block and contributors who have contributed to categories related to information technology. We obtain similar results.

6 Concluding Remarks

Private provision of public goods is greatly valued by the society. Vast majority of people contribute to various charitable causes. In 2007, 60.8 million volunteers, or about 26 percent of Americans age 16 or older, performed 8.1 billion hours of unpaid service to community organizations.[21] Economic

[19] See Wikipedia: No open proxies at `http://en.wikipedia.org/wiki/Wikipedia:No_open_proxies`, accessed May 2008, for details.

[20] A closed proxy is one that is only accessible to specific individuals. See `http://en.wikipedia.org/wiki/Wikipedia:WikiProject_on_closed_proxies/Usage_instructions` for details.

[21] According to the Volunteering in America report released on July 28, 2008 by the Corporation for National and Community Service, available at `http://www.volunteeringinamerica.gov/`, accessed November 2008.

theories suggest that free-riding is a concern in these contexts. In this paper, we utilize an exogenous shock on the group size of Wikipedia participants to study how incentives to contribute react to a change in group size. In contrast to prior studies, we find that when the group size is exogenously reduced, contributions from the remaining population decrease by approximately 41.4%.

To explain this phenomenon, we provide a simple theoretical framework to demonstrate that the reduction in contribution level may be attributed to social effects. In various empirical specifications, we consistently find that contributors who care more about social benefits react to the exogenous shock more strongly than those who value less. We interpret the reduction in contribution to Wikipedia among the unaffected contributors as evidence of existence of social effects in public goods provision. Recognition of such effects help explain the existence of charitable activities with large numbers of contributors.

Two limitations to the arguments presented in this study are important to emphasize. First, this paper studies group size and incentive to contribute in an online community. Whether we could generalize these results to traditional context of charitable giving is an interesting question for future research.

The second limitation is related to the broad definition of "social effects." Similar to how previous studies define "warm glow," we do not distinguish different motivations that give rise to social effects. This is largely due to the fact that many of these motivations lead to similar behavioral patterns. For example, contributor incentives could increase with increases in "benefits from social interactions" or "pressure from social norms." Future studies could seek to understand relative importance of different motivations.

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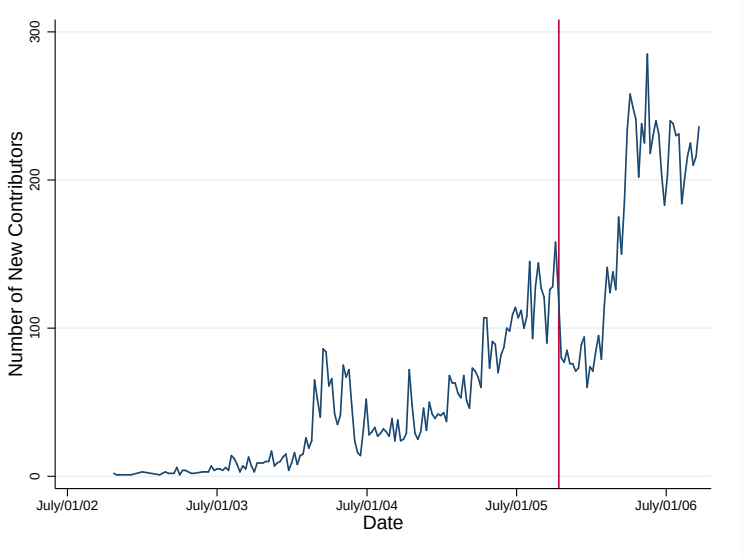
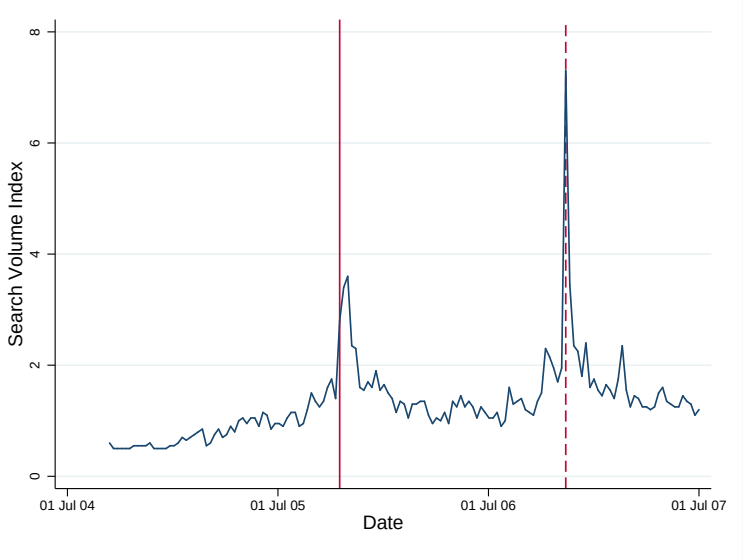


Note: The vertical line indicates the start of the third block.

Figure 1. Number of New Contributors over Time



Note: The solid vertical line indicates the start of the third block and the dashed vertical line indicates the end of the third block. The y-axis (Search Volume Index) shows users' propensity to search for a certain topic on Google on a relative basis. Google does not report the number of times a term is searched, the numbers are normalized to take the average search volume as one.

Figure 2. Search Volume Index for "Chinese Wikipedia" on Google

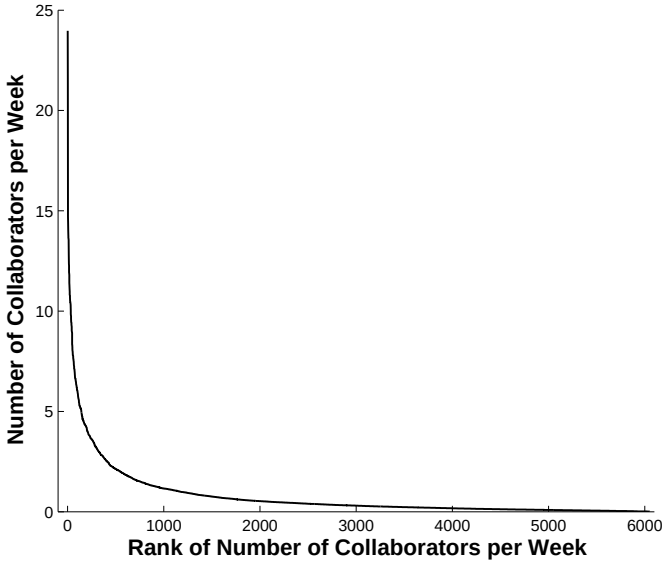


Figure 3. Distribution of the Number of Collaborators per Week for Each Contributor

Table 1. Encodings of Chinese Characters in Different Regions

Simplified Chinese (GB2312)	Mainland China Singapore Malaysia
Traditional Chinese (BIG5)	Taiwan Hong Kong Macau

Table 2. Summary Statistics for Contributions by Individual Contributors

	Pre-Block		Post-Block		Paired T-test
	Mean	Std. Err.	Mean	Std. Err.	T-stats
Panel A: Contributions from All Contributors					
Addition	1105.53	225.67	538.01	117.00	2.89***
Deletion	528.96	167.25	174.57	38.21	2.32**
Total	1634.49	389.77	712.58	153.13	2.69***
Panel B: Contributions from Unaffected Contributors					
Addition	3599.79	797.50	1910.62	413.73	2.43**
Deletion	1806.45	592.76	619.95	135.13	2.19**
Total	5406.24	1379.49	2530.57	541.45	2.37**

Note: We examine the contributions made by unique contributors before and after the block. Contributions are measured by the number of characters they added and deleted. We report the contributions made during the four weeks before October 19, 2005 in the "Pre-Block" column, and the contributions made during the four weeks after October 31, 2005 in the "Post-Block" column. In the last column, we report results from paired t-tests. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3. Detecting the Change in Individual Contribution Levels after the Block

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Total	Total	Total	Addition	Deletion	Total	Addition	Deletion
AfterBlock	−0.537***	−0.478***	−0.463***	−0.430***	−0.293***	−0.537***	−0.480***	−0.389***
	[0.044]	[0.044]	[0.044]	[0.042]	[0.032]	[0.082]	[0.079]	[0.060]
Age		−0.013***	−0.025***	−0.024***	−0.013***	−0.065***	−0.066***	−0.028**
		[0.001]	[0.002]	[0.002]	[0.002]	[0.016]	[0.015]	[0.011]
Age^2			0.000***	0.000***	0.000***	0.001***	0.001***	0.000***
			[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	13,376	13,376	13,376	13,376	13,376	13,376	13,376	13,376
Number of ID						1,707	1,707	1,707
R-squared	0.01	0.03	0.03	0.03	0.02	0.04	0.04	0.03
Specification	OLS	OLS	OLS	OLS	OLS	FE	FE	FE

Note: "Addition(Deletion)" refers to the number of characters added to (deleted from) the articles. "Total" is the sum of "Addition" and "Deletion". "Age" is the number of weeks since the contributor joins Wikipedia. "AfterBlock" is a dummy variable that takes the value 1 if the time period is after the block and 0 otherwise. Heteroskedasticity-adjusted standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4. Differences-in-Differences Estimations of the Impact of the Block on Contributors with Different Levels of Social Participation

Model	(1)	(2)	(3)
Dependent Variable	Total	Addition	Deletion
AfterBlock	-0.237^{***}	-0.214^{***}	-0.110^{***}
	[0.040]	[0.038]	[0.028]
SocialParticipation	-0.134^{***}	-0.129^{***}	-0.115^{***}
× AfterBlock	[0.026]	[0.025]	[0.021]
SocialParticipation	0.485^{***}	0.459^{***}	0.338^{***}
	[0.019]	[0.018]	[0.016]
Age	-0.028^{***}	-0.027^{***}	-0.015^{***}
	[0.002]	[0.002]	[0.002]
Age^2	0.000^{***}	0.000^{***}	0.000^{***}
	[0.000]	[0.000]	[0.000]
Observations	13,376	13,376	13,376
R-squared	0.16	0.16	0.13
Specification	OLS	OLS	OLS

Note: "SocialParticipation" is the logarithm of the weekly average of total addition and total deletion in user pages or user-talk pages by each contributor before the block. Heteroskedasticity-adjusted standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5. Differences-in-Differences Estimations of the Impact of the Block on Contributors with Different Sizes of Collaboration Networks

Model	(1)	(2)	(3)
Dependent Variable	Total	Addition	Deletion
AfterBlock	0.385***	0.370***	0.345***
	[0.055]	[0.053]	[0.043]
CollaborationNetworkSize	−0.663***	−0.625***	−0.492***
× AfterBlock	[0.049]	[0.047]	[0.040]
CollaborationNetworkSize	1.611***	1.515***	1.093***
	[0.036]	[0.035]	[0.031]
Age	0.004**	0.004**	0.007***
	[0.002]	[0.002]	[0.002]
Age^2	−0.000***	−0.000***	−0.000***
	[0.000]	[0.000]	[0.000]
Observations	13,376	13,376	13,376
R-squared	0.25	0.24	0.21
Specification	OLS	OLS	OLS

Note: "CollaborationNetworkSize" is the logarithm of the number of collaborators per week for each contributor. Heteroskedasticity-adjusted standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6. Differences-in-Differences Estimations of the Impact of the Block on Contributors using Different Character Encodings

Panel A: Regression Results

Model	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Total	Addition	Deletion	Total	Addition	Deletion
AfterBlock	−0.492***	−0.458***	−0.314***	−0.567***	−0.509***	−0.411***
	[0.046]	[0.044]	[0.034]	[0.084]	[0.081]	[0.061]
TraditionalChineseUser	0.403***	0.384***	0.292***	0.450***	0.427***	0.324***
× AfterBlock	[0.079]	[0.075]	[0.051]	[0.076]	[0.073]	[0.052]
TraditionalChineseUser	−1.290***	−1.217***	−0.805***			
	[0.064]	[0.061]	[0.041]			
Age	−0.024***	−0.023***	−0.012***	−0.066***	−0.066***	−0.029**
	[0.002]	[0.002]	[0.002]	[0.016]	[0.015]	[0.011]
Age^2	0.000***	0.000***	0.000***	0.001***	0.001***	0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	13,376	13,376	13,376	13,376	13,376	13,376
Number of ID				1,707	1,707	1,707
R-squared	0.05	0.05	0.03	0.04	0.04	0.03
Specification	OLS	OLS	OLS	FE	FE	FE

Panel B: Effect of Block on Contributors Using Traditional Chinese

AfterBlock +	−0.089	−0.074	−0.022	−0.117	−0.082	−0.087
TraditionalChineseUser	[0.064]	[0.060]	[0.038]	[0.094]	[0.092]	[0.066]

Note: "TraditionalChineseUser" is a dummy variable which takes 1 if a contributor uses Traditional Chinese and 0 otherwise. Heteroskedasticity-adjusted standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.