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Collapse of an Online Social Network: The Blame on Social Capital

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Collapse of an Online Social Network: The Blame on Social Capital

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Abstract

The rise and popularity of online social networks is a recent phenomenon. In this study, we analyze the reasons and mechanisms behind the collapse of an online social network (OSN), iWiW. Significant cascading mechanisms have been identified in the pattern of abandoning the site at its peak of popularity and after. It is of key importance to study who were the key actors that started these cascades and abandoned the site early compared to others in their network. We contrasted explanations based on preserving accumulated social capital vs. building new social capital with motives influenced by innovativeness. On the one hand, those who are well embedded in their existing network have more to lose. On the other hand, people might want to escape from redundancy and indebtedness indicated by a high local clustering coefficient. We find with heterogeneous choice models that lower degree and a high local clustering are associated with early abandonment. The significant effects of age and innovativeness that depend on the life stage of the OSN indicate that mechanisms related to social capital are not the only reasons for the collapse.

JEL: D70, D85

Keywords: online social networks, social capital, innovation, embeddedness

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Egy közösségi háló összeomlása: a társadalmi tőke szerepe

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Összefoglaló

Az online közösségi hálózatok felemelkedése és népszerűsége új jelenség a társadalomban. E tanulmányban egy közösségi hálózat, az iWiW *összeomlása* hátterében található okokat és mechanizmusokat elemezzük. Jelentős hálózati hatások figyelhetőek meg az oldal elhagyásában annak népszerűsége csúcsán, és az ezt követő időszakban. Fontos tehát megvizsgálni, hogy mely felhasználók indították e lavinákat azzal, hogy az ismerőseik előtt elhagyták az oldalt. Ennek során a felhalmozott társadalmi tőke, illetve az innovativitás kapcsán kiépített új társadalmi tőke magyarázatát vetettük össze. Egyrészt ugyanis azoknak, akik jelentős hálózati befektetéssel rendelkeznek, több vesztenivalójuk van. Másrészt viszont a szoros és zárt kapcsolatok redundanciát és elköteleződést jelentenek, melytől a felhasználók szabadulni szeretnének. Heterogeneous choice modellek alkalmazásával azt találtuk, hogy az alacsony fokszám és a magas lokális clustering koefficiens összefüggnek a hálózat korai elhagyásával. A kor és az innovativitás szignifikáns hatásai azonban azt mutatják, hogy a társadalmi tőke mellett más mechanizmusok is szerepet játszanak a hálózat összeomlásában.

JEL: D70, D85

Tárgyszavak: Online közösségi oldalak, társadalmi tőke, innováció, beágyazottság

INTRODUCTION

SOCIAL CAPITAL AND OSNS

The rise and popularity of online social networks (OSN) in the new millennium overshadows even the success of the internet itself. The sociological reasons behind the phenomenon are relatively well studied (e.g., Boyd, 2008; 2014). Explanations concentrate on different aspects and motives of social capital that include emotional (e.g., sense of belonging) as well as practical (e.g., access to information) reasons of participation. Today, when Twitter and Facebook are so ubiquitous and users spend many hours every day interacting through these sites, it is difficult to fathom how OSNs could collapse at all.

At the systemic level, pre-mature OSNs have been abandoned for new and more adaptive ones. In some cases, they have simply been shut down by the provider. Such system-level explanations, however, do not enrich us with a deep understanding of user behavior that is typically independent of or precede provider decisions. It is more insightful to search for explanations at the individual and micro-structural level. Particularly important for the fate of an OSN is the behavior of certain key actors: those who bring a lot of users with them into or out of the site. In this study, we analyze individual and structural mechanisms that triggered users to abandon the site early in their network, starting a cascade.

As theories of social capital have been useful in explaining the popularity of OSNs, they could also be potentially useful for the explanations of their abandonment. Moreover, by looking at abandonment, we might also gain new insights about the dimensions of social capital that played a role in encouraging active participation.

According to the most general definition, social capital is investment in social relations with expected returns (Lin, 1999). The literature agrees that having more connections is generally useful. Beyond this, however, there is less agreement. The tradition following Coleman (1990) emphasizes the importance of dense and closed networks, as they are useful for sanctioning non-conforming members, thus fostering trust and cooperation. On the other hand, Burt (1992) argues for the redundancy of ties in a closed network and highlights the usefulness of bridging positions. Individuals with structural holes in their network can access different information and may exercise control over that. Resolving these divergent views on social capital, it can be ascertained that denser networks may have a relative advantage for preserving and maintaining resources, while more open networks for searching and obtaining resources and information (Podolny and Baron 1997; Lin 1999; Gargiulo and Benassi 2000; Borgatti and Halgin 2011)

This duality is reflected in the rich literature on embeddedness (Granovetter 1985; Uzzi 1997). There has been ample evidence that the relation of social networks, social relationships and social capital to beneficial outcomes for individuals might be inversely U-shaped. Social capital is a double-edged sword and over-embeddedness implies indebtedness and inflexibility (Granovetter 1985; Uzzi 1997). Therefore, if we aim to understand the importance and influence of online social networks on people's lives, we must take positive as well as negative effects of relationships into account (Portes and Sensenbrenner 1993; Gargiulo and Benassi 1999; 2000).

Friendships take away time and opportunities from other things, such as productive work. Though it might be considered minor on OSNs, each tie involves costs of relationship maintenance. Piling up relationships results in a network that is simply too big to maintain effectively on a regular basis, or in a loss of productivity because of time budget constraints. This phenomenon has been described as network overload (Steier and Greenwood 2000). A different aspect of relationship costs is that having many ties might be a psychological burden to people (Krackhardt 1999). Strong embeddedness also implies obligations that are uncomfortable to maintain (Granovetter 1985; Coleman 1990; Burt 1992; Nahapiet and Ghoshal 1998) and the implicit need of open disclosure of personal information (Agneessens and Wittek 2011). In practice, being locked-in on an OSN might imply unwanted exposure of personal information.

Seen from the perspective of individual motivations, over-investment in relationships may occur because "people cannot predict the future and do not want to be caught on the wrong side"(Flap 2002). Heavy involvement on OSNs, however, might lead to addiction and dependency: "ties that bind may be ties that blind" (Uzzi 1997; Cohen and Prusak 2001), which has also been described as being locked-in (Johannisson 1996).

MICRO EXPLANATIONS FOR THE UPS AND DOWNS OF OSNS

The shift between the popularity of online social networks cannot be reduced to a single motivational factor. Previous research points to a complexity of reasons and mechanisms that underlie the decisions behind leaving one site for another.

The first explanation relates to contextual effects of human life. All ego-networks are divided by contexts and we experience radical changes in our social network when going through certain life events. A list of such defining events could include: going to secondary school or college, changing of the workplace, moving to another city, adopting a new hobby, joining a voluntary association, a breakup or divorce, a new romantic partner, or having children. Our social networks as well as our online social networks are very much clustered

locally along these different contexts (Fischer 1977; Feld 1981). Just like with adapting to a new software environment at our new workplace, we might easily adapt to a different OSN that popular in our new community context.

Facebook's overtake of MySpace was perhaps the most notable reconfigurations of the online social network landscape at the end of the first decade of the millennium. When studying user preferences, authors pointed to the perceived differences between the sites in terms of maturity and a more conscious digital presence management on the part of users. Boyd (2008) explored the crucial period of 2006 and 2007, when the competition between the two sites was intense. Among US teens, even though the choice was often framed around the presence of friends, specific features, aesthetics, or perceived greater safety, "preference" was the reflection of broader teen social structures. Although many teens who joined Facebook were never present on MySpace or maintained their MySpace account even after joining Facebook, switching was often a "rite of passage between high school and college" (Boyd 2008: 213). Robards (2012) also explored the shift from MySpace to Facebook in terms of a transition from adolescence to adulthood. Participants in his study described MySpace as a place for peers where the performative conventions were more introspective, hence the qualities in focus could be described as more "juvenile". Facebook was considered to involve familial and other 'adult' relationships more likely and evoked a desire for a more conscious digital trace management. Wilkinson and Thelwall (2010) found that the continued predominantly young membership of MySpace suggests that using the site may be a life-phase activity more than a cohort-based activity where one contributing factor could be Facebook's less customizable, more functional interface that could be appealing for more mature audiences.

The second explanation is built on individual preferences for different features on the sites. Facebook, for instance, is viewed as more mature, sterile, and boring than MySpace, this induces a stronger preference by more educated users (Lenhart et al. 2010). Concerns about the type of information presented and questions of privacy could have also made Facebook more attractive to certain users (Patchin and Hinduja, 2010). This explanation contributes to our understanding of the differences in the social background of users on different sites, but such an explanation is insufficient in predicting the massive abandonment of an OSN.

CASCADE DYNAMICS

What makes the case of changing online social networks special is the obvious presence of network externalities. Network externalities refers to how the utility of the consumption depends on the number (and the structure) of connected users of the service (Katz and

Shapiro 1992). Network externalities create a switching cost for customers and an entry barrier for alternative providers (Economides 1996). This implies that initially the new platform has to provide far superior services for a critical mass of users to switch. Once this critical mass is reached, however, joining the new platform becomes self-reinforcing.

OSN users connect with people they already know offline (Boyd 2008). Without a critical mass of known contacts on a particular OSN, its functions have a very limited utility. It means that the utility of a platform to a user depends on the number of platform users among the user's connections. This clearly implies a cascade mechanism in changing between the platforms. If users switch, the new platform becomes more attractive to their friends. In line with this, it was found that the more friends leave a provider on the mobile phone service market, the higher the probability of churn (Dasgupta et al. 2008). Similarly, a study of an OSN found that the number and the share of inactive friends increase, while the number of active friends decreases the probability of leaving the site in the subsequent period (Wu et al. 2013). The cascade mechanism may progress through the entirety of the network, or alternatively, it may stop at boundaries between closely connected subnetworks. The model of Garcia, Mavrodiev, and Schweitzer (2013) suggests that in the presence of network externalities given the number of connections, a locally dense structure (high k-coreness) increases the resilience of the network. When examining five online social networks empirically, however, they found that currently successful OSNs have relatively low k-coreness compared to failed or declining ones.

Beyond the degree, other structural properties may be important when analyzing the decision of staying or leaving. In the analysis of the churn of mobile phone service users, it was found that churn was not only dependent on the number of friends left, but also on the connectedness of these friends. If they formed a connected subgroup, the probability of churn increased further (Dasgupta et al. 2008).

NETWORKS AND DIFFUSION OF INNOVATIONS

In addition to the social capital literature, the research on the diffusion of innovations also has implications for the life cycles of OSNs. The early network diffusion studies (Coleman, Katz, and Menzel 1966; Becker 1970) suggested that high degree in the network is correlated with more innovative behavior, thus the adoption of the innovation earlier (Valente 1996). It was also shown that central members of a community (opinion leaders) can be used to accelerate the diffusion of an innovation (Valente and Davis 1999). Another perspective suggested by Burt (1999) is that opinion leaders are brokers between groups, who influence their own group while allowing to spread the innovation across boundaries. Thus, when investigating the network position of innovators, we can use the same argument about the

advantage of bridging positions (Burt 1992) that we have used for assessing the value of the old network.

These arguments, however, become less clear, when we try to dissect the mechanisms leading to the collapse of an old network. The diffusion of innovations approach suggests that people in more central and more open network positions are more likely to be opinion leaders, who start using new services first. Given the time constraints of users, we assume that their increased engagement with the new platform leads their abandoning of the old site. Consequently, bridging members would be more likely to start the avalanche. From the point of view of social capital accumulated on the old site, however, we expect that the old site has the highest value for users with a high degree and open connections. Thus the collapse of the network is expected to start from the periphery.

This conflict between predictions is based on two implicit assumptions. The first is that the network position of an individual in the observed online social network is similar to her position in the social network relevant for adopting an innovation. The second assumption is that joining a new network automatically goes together with leaving the old one. This is apparently true as a general tendency, as it is usually inefficient to manage one's social network using several sites. A dual practice, however, might be maintained in specific situations. Boyd (2014) describes the mechanism behind the phenomenon as context collapse. In these cases, unwilling to share their information or content with all their connections, users engage with different social subgroups with distinct norms and expectations via different OSNs. If context collapse is relevant, people with diverse networks are expected to join the new platform relatively early; however, they may also stay with the old platform longer.

IWIW: AN ABANDONED OSN

We investigate the sociological and structural mechanisms explaining the abandonment of OSNs using the example of a once highly popular Hungarian site iWiW. iWiW (international who is who, originally WiW) was founded in 2002. It was one of the first online social networks in the world and the most popular online social network in Hungary until October 2010, when its popularity was exceeded by that of Facebook (Webisztan, 12.10.2010). iWiW started as a small innovative non-profit project and it was exclusively based on invitations in its emerging stage. As it grew, the site was bought by Hungarian Telekom in 2006. Afterwards, it gradually took up a less personal, more corporate identity. Facebook was launched in Hungary in October 2008 and was available in Hungarian from April 2009. Although often criticized for its inadequate speed and many bugs, at the time of Facebook's arrival, iWiW had more than 3 million active users (in a country with a population of 10

million this meant two-third of all Internet users). To maintain its market position, iWiW went through several redesigns. Redesigns were improvements of service, but also reactions to the proliferation of user generated advertisements and viral marketing. Despite the innovations, the OSN gradually lost its popularity; after experiencing a striking decline in user activity. iWiW was finally shut down by the provider in 2014, becoming a part of social and internet history.

Such radical shifts are not rare in the landscape of online social networks. In 2008, the world map of the leading OSN services was quite colorful, yet today, in most countries Facebook dominates.

USES AND FUNCTIONALITIES OF IWIW AND CONTEMPORARY OSNS

For understanding whether mechanisms related to social capital played an important role in abandoning the site or not, it is essential to go through the key functionalities of iWiW and contemporary OSNs. OSNs are socio-technical systems where technical affordances, social norms, and practices that guide user engagement are in a fluid interplay contributing to a constantly shifting, evolving environment (Ellison and Boyd 2013). Today most OSNs are organized around a stream of recently updated content (e.g. Facebook's News Feed). They are able to fulfil the function of social grooming in an entertaining way between people who feel attachment or belonging to each other (Ellison et al. 2014).

Earlier OSNs were much more profile-centric. Prior to 2007, the three defining features that constituted the core of OSN functionality were the profile, the connection lists, and the ability to traverse those connections (Ellison and Boyd 2013). Profiles, as on iWiW, were designed to be static portraits, constructed and updated through text and images by the profile owner. iWiW was generally regarded as a useful digital phonebook (by default, the email address of every member was visible), and was criticized for its lack of dynamic content. The visibility and the exploration possibility of connections were the most luring features of iWiW. For many years, the site offered a visualization of the user's social network with the possibility of showing the shortest path to any member. Connections of anyone could be displayed, which was highly useful for building new ties, partnerships, and finding new job opportunities.

SUMMARY OF HYPOTHESES

Given the key functionalities of keeping contact, obtaining resources and information, the information aspect of social capital could be especially relevant for using the site. From the

information aspect, having a large number of ties and diverse ties (more open network structures) are useful (Burt 1992; Lin 1999), hence we expect that:

H1: Users with higher degree on iWiW are less likely to abandon the site early.

H2: Users with more open networks on iWiW are less likely to abandon the site early.

Furthermore, we noted that more innovative users (opinion leaders) would have been more likely to join Facebook early; therefore they may also have abandoned iWiW early. Unfortunately, we do not possess information on the time of joining Facebook. What we can rely on is the structural position on iWiW, which, however, corresponds well to the information aspect of social capital provided by it. Therefore, we use the relative time of joining iWiW as a proxy of innovativeness. We put forward the following prediction:

H3: Innovative users are more likely to abandon iWiW early, controlling for the degree and openness of their networks.

Most of our arguments about who starts a cascade are sensitive to the actual popularity of the OSN. Personal motivations change over time and they are different at the stage of rising popularity and at the stage of decline. The determinants of who abandons the site early are expected to depend on the availability of outside alternatives. Innovativeness, in particular, is expected to be influential in prompting early leave before and around the peak of popularity, but not later.

H4: Innovative users are more likely to abandon iWiW earlier than others in their network before the peak of popularity of the site, but innovative users who stayed longer are not expected to start a cascade in their network.

DATA AND METHODS

The entire iWiW network, along with a few individual level variables, was archived in 2013 and an anonymized dataset by compiled by the provider. This dataset was purchased and has been made available for scientific analysis. The dataset includes users' first and last login dates, self-declared place of residence, self-declared age (N=4,610,996) and contains information on all network connections together with the date of their creation (N=924,247,707 directed ties). As the vast majority of users left the site without deleting their profiles, the dynamics of abandoning the site can be analyzed using the last login date. The last login is also an appropriate choice because users could see the last login date of anyone on iWiW, therefore their perception of the viability of the OSN was influenced by this information.

The analysis focuses on the period between 2007 and 2012. We did not analyze the years of growing popularity prior to 2007, as there was very low churning. We also excluded the final year of 2013, when the network became essentially abandoned. Users were excluded

from the analysis if they registered on the site but never used it, if their last login date was missing, if they had zero connections or had more than 2,000 connections. The upper limit was used to exclude celebrities, politicians, and users with commercial interests. These conditions altogether resulted in the exclusion of 7.6% of cases. In addition, users under the age of 14 were deleted (10.8% of cases). The resulting dataset includes 3,762,529 individuals and 796,810,090 directed connections. Basic descriptives are summarized in Table 1.

Table 1.

Descriptive statistics

Variable	mean	s.d.	Valid N
Age at registration	32.62	12.93	2,495,067
Registration day	30 Oct. 2007	569.5 days	3,762,529
Last login day	22 Apr. 2012	424.7 days	3,762,529
Gender (1=women, 2=men)	1.45	0.50	3,762,529
Country (1=Hungary, 0=other)	0.88	0.33	3,762,529
N of confirmed connections	210.0	203.4	3,762,529
N of unreciprocated connections	1.77	5.82	3,762,529

MEASURES

Our dependent variable is based on the classification of users. Users who abandoned the site when at least 90% of their connections were still active are called 'early leavers' and their last login date is labeled as 'early abandonment'. 'Non-early leavers' for a given year are those whose last login took place in the given year, but less than 90% of their connections were still active. 'Stayers' are those whose last login was later than the actual year. As there is no apparent cut-point in the probability distribution of abandoning the network depending on the number of active friends, to check the robustness of the results, we also created models with alternative thresholds of 95% and 80%.

We used the number of confirmed connections (symmetric relationships) as one of the key independent variables related to social capital based mechanisms. The definition of early abandonment is not completely independent from degree. Users with less than ten connections are counted as early leavers if they abandon the OSN earlier than any of their friends. However, only by chance, one has higher probability to be the first in the group of two than in the group of ten. Therefore, early abandonment is by construction positively correlated with degree for very low degrees. To overcome this spurious correlation, we also checked the validity of our results excluding users with less than ten connections.

As a measure of the information aspect of social capital, we measured the openness of the ego-network by the local clustering coefficient (Watts and Strogatz 1998; Holme and Kim 2002; Jackson 2008; Opsahl 2013):

$$LCC_i(g) = \frac{\sum_{j \neq i; k \neq j; k \neq i} g_{ij} g_{ik} g_{jk}}{\sum_{j \neq i; k \neq j; k \neq i} g_{ij} g_{ik}},$$

where i, j, k reprensent nodes of network g, and g_{ij} represents an edge between them. LCC thus runs from zero till one, and describes the extent to which ties (g_{jk}) are present in the ego-network (of node i) among its alters $(g_{ij} \text{and } g_{ik})$. We opted for LCC rather than for other candidates, such as constraint (Burt 2000) or betweenness centrality, because it is in line with the theoretical arguments, it is easily interpretable, and its calculation for a huge network is not computation-intensive.

Innovativeness was measured with the difference (in days) between the date when one joined iWiW and the average date when users of the same age joined. Thus, its positive values signify a more innovative behavior meaning that these users joined the network earlier than others of the same age.

METHOD

Hypothesis H4 predicts that the effects of user characteristics change over time. The test of H4 and other hypotheses, the complex structure of the data set, and the appropriate handling of the dependent variable of early abandonment require a careful method selection.

The use of proportional hazard models is not fully appropriate because these models assume that the coefficients of the independent variables are the same over time (Allison 1982). This assumption does not allow testing of hypothesis H4. A second option is to use binary logistic regression with interaction terms over time or several binary regression models for different time-periods. This method is also problematic because the coefficients (and their standard errors) depend on the residual variation, so they are not comparable across models or in between interactions (Allison 1999). There are potential solutions to this problem (Allison 1999), but they have their own drawbacks (Williams 2009). Therefore, we opted for the more flexible heterogeneous choice model approach (Williams 2009). Based on Keele and Park (2006) and Williams (2009), the heterogeneous choice model with a binary outcome variable of early abandonment (y_i) is defined as:

$$\Pr(y_i) = g\left(\frac{x_i\beta}{\exp(z_i\gamma)}\right) = g\left(\frac{x_i\beta}{\exp(ln(\sigma_i))}\right) = g\left(\frac{x_i\beta}{\sigma_i}\right),$$

where g is the logit link function (that also can be probit). In the numerator, x_i is the vector of independent variables for observation i, and β is the vector of coefficients. This part of the

model is called the choice equation (and it also contains a constant term). In the denominator, z_i is the variable, by which values we assume that there is different residual variation (in our cases, time) and γ is its coefficient of the effect on the variance. This part of the formula is called the variance equation. Variables in the variance equation model can be dummy or continuous variables, but in both cases we have to assume a linear effect on the error variances (e.g., as time passing by, error variances decrease). As we assume that the error variances do not change linearly, we included time-periods as dummy variables in the variance equation and used the same variables as interaction terms in the choice equation. We used the STATA oglm program for the analysis (Williams 2010).

RESULTS

BASIC DYNAMICS

Figure 1 shows that iWiW reached a saturation point in 2010, two years after the appearance of Facebook in Hungary. A gradually increasing churn rate can be observed. In 2010, 6% of the users abandoned the site. Before 2011, we do not see a proliferation of this behavior: less than one percent of users can be categorized as non-early leavers in these years. The turning point was 2011, this is when the avalanche starts (Török, Ruan, and Kertész 2016). Churning reached 13% and most users lost at least 10% of their connections. Hence there was a boom in the share of non-early leavers.

Figure 1.

Dynamics of abandoning the network

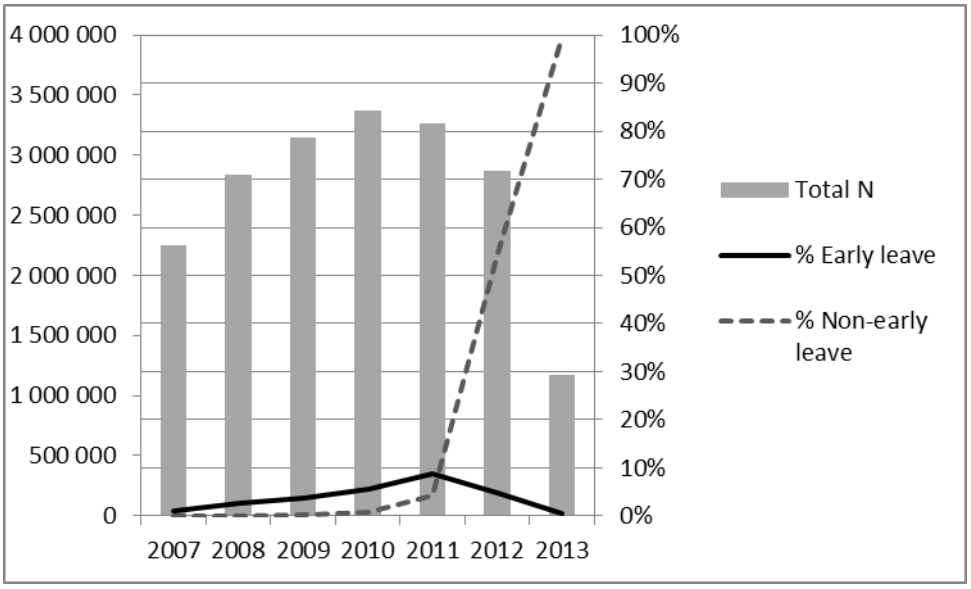
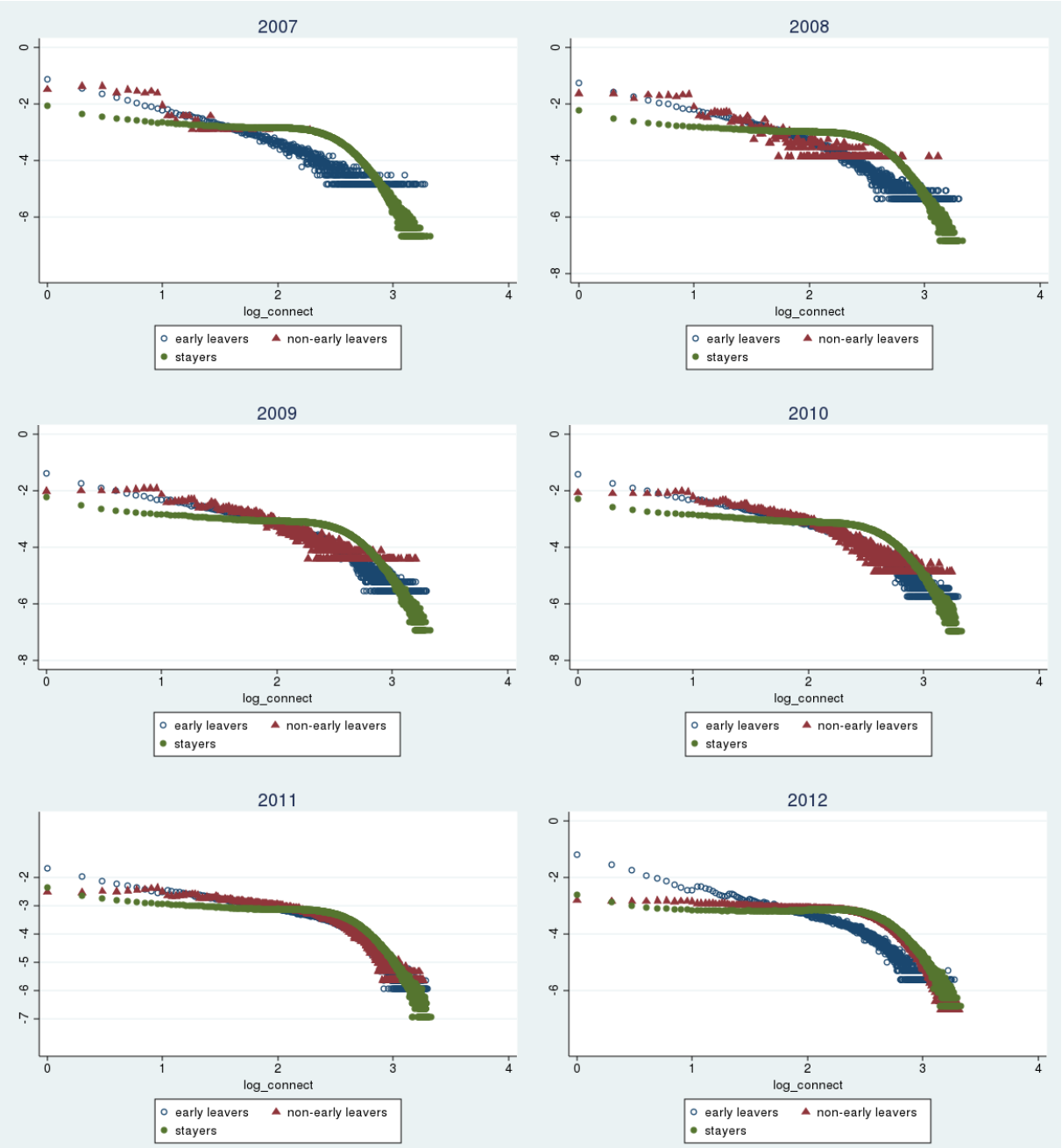


Figure 2 depicts the yearly degree distributions of early leavers, non-early leavers and stayers. It is visible that users with a low number of connections are more prevalent among retreats than among stayers. Towards the year 2011, the degree distributions of early and non-early leavers approach the one of stayers, suggesting that the churning becomes more general. In 2012, the degree distribution of early leavers again indicates an excess number of low degree users compared to stayers. This may be due to the fact that peripheral users were less affected by losing 10% of their network in 2011, when contagion reached its peak.

The differences in the degree distributions suggest that peripheral nodes were more likely to be early leavers than what could have been expected from random chance. This difference is underlined with the analysis of the probability of early abandonment in association with the number of connections (Figure 3). Interestingly, the effect of the number of connections seems to turn around over approximately 600 friends. It seems that, except for the year 2012, superhubs were more likely to leave their network early than people with many connections.

Figure 2.

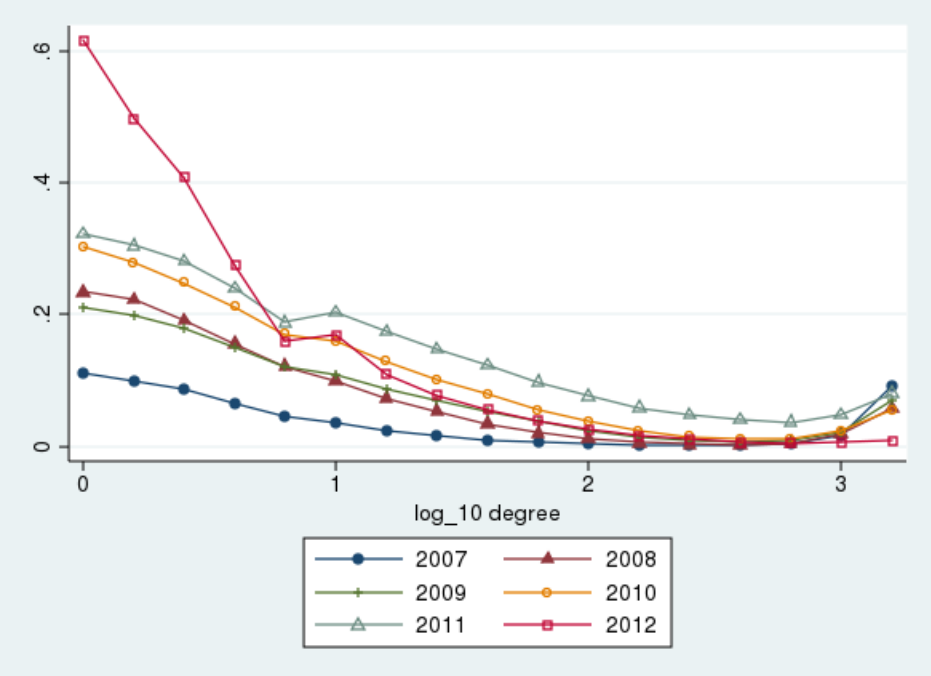
Degree distributions of early leavers, non-early leavers and stayers by year (log-log scale)



Notes: Distribution functions of degrees (k). Y axes: log P(k), X axes: log k.

Figure 3.

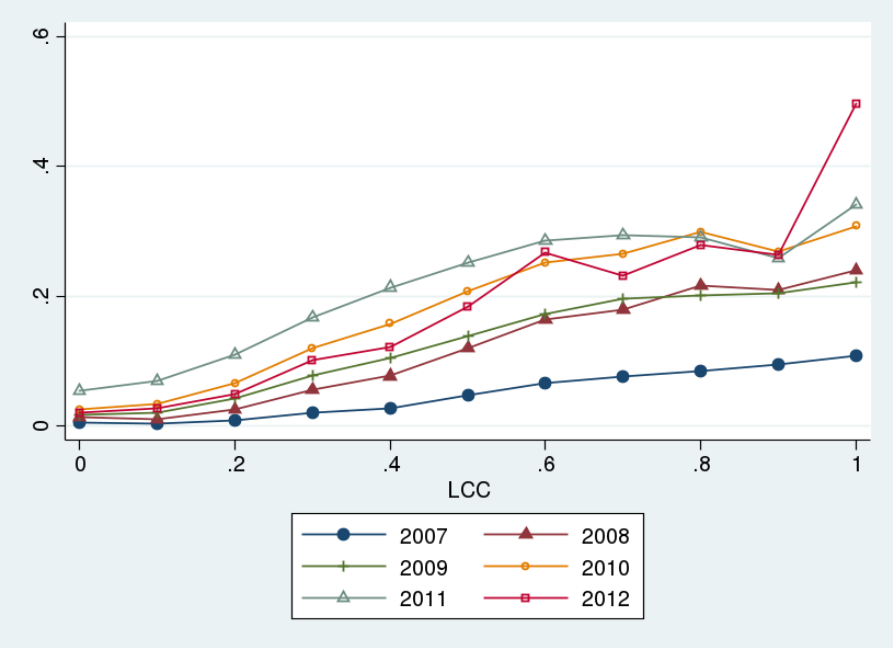
Probability of early leave by log degree and year



When considering the relationship between local clustering and early abandonment, the restraining effect of locally open (less clustered) positions is visible, together with the gradually increasing probability of early abandonment from 2007 to 2011 (Figure 4).

Figure 4.

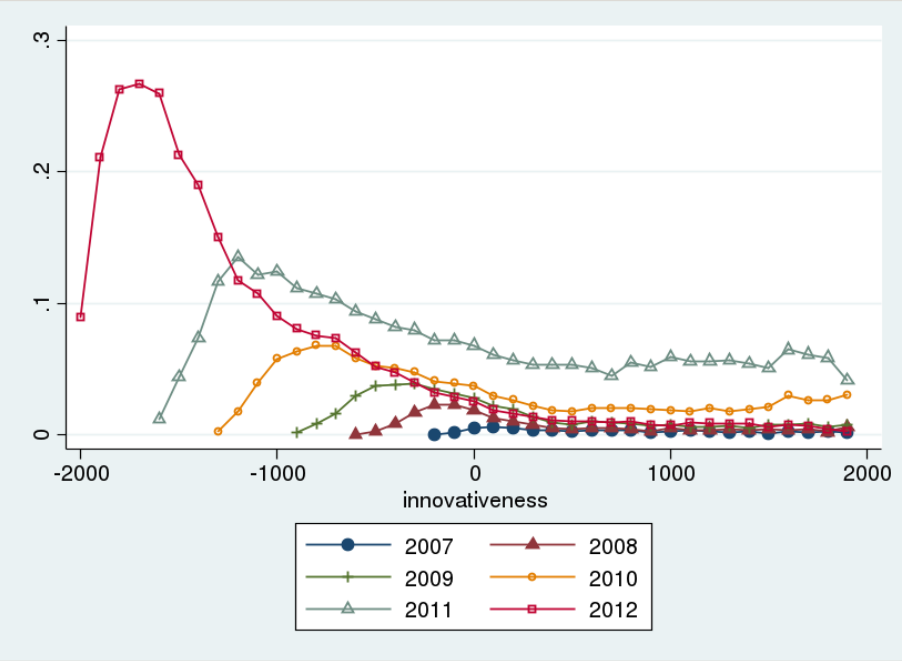
Probability of early abandonment by local clustering and year



A non-linear relationship can be observed between innovativeness and early abandonment (Figure 5). This can be interpreted as follows. Users, who already leave the site in 2007, have a certain minimal level of innovativeness, because all of them arrived in or before 2007. So in each group of users abandoning the site early in a given year, innovativeness is censored from the left. For instance, the line for 2007 contains only innovative users. The left side of each line in Figure 5 represents non-innovative users, who joined iWiW late, but became early leavers in their network. All curves have an increasing part, representing that it is not the latest people to join, who are the ones who leave early in their network. This could also mean that even late adopters give a chance to the OSN, and as they gain some experience, they are more likely to leave. The right side of each line indicates that innovative users, who joined early and spent a long time in the network, are less likely to abandon the OSN early. This could mean that people become more attached to the OSN over time.

Figure 5.

Probability of early abandonment by innovativeness



Notes: Innovativeness is measured by the relative time of joining iWiW. Innovative users (early adopters) are displayed on the right side of the Figure.

We should not draw far-reaching conclusions based on two-way analyses, however, as the variables of interest are strongly correlated (Table 2). The negative relationship between degree and local clustering indicates that people start building their network with strong ties, connecting with people, who typically know each other. As individual involvement and the

ego-network grow, more and more people are included from different social circles. The positive correlation between degree and innovativeness represent that the innovative users, who joined the network early, also tend to have a larger network on iWiW. For example, users registered in 2002 have a median of 692 connections, while for those who registered four years later this number is only 610. For the sake of a more reliable interpretation, it is important to mention that those who were more innovative spent more time on iWiW, in turn, they had a longer time period to accumulate connections.

Table 2.

Pairwise correlations between the key independent variables

	log degree	LCC	Innovativeness
log degree	1.000		
LCC	-0.559	1.000	
Innovativeness	0.487	-0.374	1.000

MULTIVARIATE ANALYSIS

We used heterogeneous choice models for assessing the effects of user characteristics and local clustering on abandoning the network early, and for comparing the change of its magnitude across years. This was expressed by adding time variables and interactions with time variables to the choice model. We divided the analysis into three periods: the initial years (2007-2008), the first years following the entry of Facebook (2009-2010), and the years of decline (2011-2012). Heterogeneous choice models are specified as the main effects correspond to the baseline years 2009-2010. Interactions with 'year = 2007-2008' and 'year = 2011-2012' test whether the effects are different in the preceding or in the subsequent years (Table 3).

Results support social capital related explanations. Individual degree, in its logarithmic scale in particular, decreases the chance of abandoning the OSN early. This means that the information aspect of social capital played a very important role in keeping key actors on iWiW, which confirms hypothesis H1. Interactions suggest that the effect of connectedness decreases over time, being the largest in the initial years.

Interestingly, in contrast to the two-way analysis (Figure 3), we do not find that the effect of degree would turn around for hubs. (This could be apparent, if the logarithmic effect of degree had the opposite sign as that of the main effect.) We checked this result also with alternative specifications (not shown here) and arrived at the same conclusions.

The additional positive effect of locally open networks is confirmed: a high local clustering coefficient is associated with higher probability of leaving the network early (H2).

Those who abandoned the site early were more likely to have a highly clustered, redundant network. From the effect size of the local clustering coefficient one can conclude that the explanation related to structural holes is central for detecting who would start the avalanche. In contrast to the effect of connectedness, the effect of local clustering is decreasing over time. As interactions show, higher local clustering induces early abandonment throughout the examined period, but this effect is the weakest in the initial years and the strongest is in the last ones.

Furthermore, innovativeness has a small significant effect (H3) in the period of Facebook's entry (2009-2010). Those who joined earlier than a typical member of their age group tended to abandon the site early. The effect is small in magnitude, and hence its importance lags behind the mechanisms related to social capital. Furthermore, in the collapsing years an interaction effect with the opposite sign and approximately the same magnitude is found. Added to the main effect, the interaction indicates that innovativeness does not exert any positive effect in this period (H4).

Considering the control variables, it is visible that older users are more likely to leave the network early. Not surprisingly, users with more rejected ties are more likely to leave the network early.

Given the large and complete data, traditional significance tests should not be considered as in sampling based surveys. Small effect sizes indicate differences, but misguide the interpretations of the results for core explanations (Golder and Macy 2014). In addition to the analysis of odds ratios, marginal effects should also be considered when one judges the presence of a relevant mechanism (Bartus 2003).

Odds ratios from the above estimates indicate substantive differences. For example, increasing the number of connections from 100 to 200 decreases the chance of early abandonment by 39%. Similarly, a decrease in the local clustering coefficient from 0.2 to 0.1 is associated with a 28% decrease in early abandonment. Average marginal effects corresponding to the estimates (Table 3) are much smaller. This is due to the fact that we predict a relatively rare occurrence: early abandonment constitutes only 22.2% of all users. We examine this throughout the users' life-cycle, therefore in a given year, early abandonment has a probability of 0.046 only. The average marginal effects predict that increasing the size of one's network from 100 to 200 is associated with a 0.56 percentage point decrease of early abandonment. This number seems to be small in itself, but it is still sizable compared to the 4.6% average.

Table 3.

Predictors of early abandonment

Variables	Coefficient	S.E.	Marginal effect
Main effects			
Age at registration	0.00211***	0.000209	0.0000247
Innovativeness	0.000377***	7.56e-06	4.43e-06
Degree	-0.00183***	3.86e-05	-0.0000215
Ln(degree)	-0.426***	0.00413	-0.00500
Non- reciprocated ties	5.734***	0.0870	0.0673
LCC	1.314***	0.0182	0.0154
year = 2007-2008	-0.787***	0.0609	0.0200
year = 2011-2012	-0.154	6.030	0.0302
Interactions with year = 2007-2008			
Age at registration	-0.0175***	0.000742	-0.000206
Innovativeness	0.000211***	3.51e-05	2.47e-06
Degree	-0.00201***	0.000177	-0.0000236
Ln(degree)	-0.526***	0.0210	-0.00618
Non- reciprocated ties	10.89		0.128
LCC	-0.428***	0.0480	-0.00502
Interactions with year = 2011-2012			
Age at registration	0.00209	0.0142	0.0000245
Innovativeness	-0.000408***	0.000104	-4.79e-06
Degree	0.00160*	0.000801	0.0000188
Ln(degree)	-0.233	2.227	-0.00273
Non- reciprocated ties	-4.867	2.935	-0.571
LCC	0.889	7.453	0.0104
Variance (lnsigma)			
year = 2007-2008	0.406***	0.0175	
year = 2011-2012	0.422	3.382	
Thresholds			
Cutpoint 1	1.629***	0.0189	
N (user-years)	12,486,426		

*Notes: Heterogeneous choice (oglm) models. ***: p<0.001, **:p<0.01, *:p<0.05*

ALTERNATIVE SPECIFICATIONS AND ROBUSTNESS CHECKS[1]

For early abandonment, two conditions must be satisfied. First, the user needs to abandon the site in the given year. Second, more than 90% of his or her ties still need to be active users in the given year. Only the first can be directly attributed to the user's behavior, while

[1] We used a random sample of 10% users for the robustness checks, as the computations are time-consuming. As a justification for sampling, we repeated the same analysis that has been performed for the entire data set and reported in Table 3 for random samples of 10% users. Our results have shown that given the huge amount of observations and the scaling of our key variables, this restriction does not affect the results.

the second is based on others' decisions. Therefore, it is interesting to examine uniquely those situations, when the user is still able to leave early, and to exclude those person-years, when more than 10% of the user's social connections have already left. In contrast to the baseline model, this analysis represents user choices more closely, which is more related to the differences between primary retreats and non-primary retreats. Results of the main effects are similar to the ones we found in the baseline specification: high degree is associated with lower probability of leaving the network early (Table 4). A high local clustering coefficient and high innovativeness increase the chance of early leave. The alternative model specification offers clear-cut results for time-dependent effects. The interaction terms are not significant in the 2007-2008 period, but most of them gains significance in 2011-2012. So the importance of factors, on which the choice of early abandonment depended, changed over time.

Early abandonment has been defined with a 10% threshold in the connections of the individual. To check the robustness of the results, alternative specifications of 5% and 20% were also used (Table 4). The results with alternative specifications are only slightly different. While most conclusions are the same, the time-dependent effect of innovativeness seems to depend on which thresholds are applied.

Table 4.

Predictors of leaving the network early (alternative specifications)

Variables	(1) only when the user is still able to leave early	(2) 5% threshold of early abandonment	(3) 20% threshold of early abandonment
Main effects			
Age at registration	0.00180**	0.00684***	-0.00134*
	(0.000665)	(0.000704)	(0.000646)
Innovativeness	0.000416***	0.000308***	0.000431***
	(2.42e-05)	(2.60e-05)	(2.33e-05)
Degree	-0.00200***	-0.00158***	-0.00218***
	(0.000125)	(0.000131)	(0.000122)
Ln(degree)	-0.430***	-0.449***	-0.429***
	(0.0132)	(0.0138)	(0.0127)
Non- reciprocated ties	6.264***	5.659***	6.544***
	(0.280)	(0.290)	(0.271)
LCC	1.284***	1.301***	1.217***
	(0.0578)	(0.0599)	(0.0560)
year = 2007-2008	-0.00159	-0.993	-0.984
	(10.32)	(12.53)	(33.74)
year = 2011-2012	0.746***	0.692	0.261***
	(0.0848)	(2.017)	(0.0711)
Interactions with year = 2007-2008			
Age at registration	-0.0102	-0.0194	-0.0125

	(0.0552)	(0.0541)	(0.198)
Innovativeness	1.14e-05	0.000455	0.000218
	(0.00279)	(0.00329)	(0.00929)
Degree	-0.000820	-0.00328	-0.00229
	(0.0184)	(0.0210)	(0.0639)
Ln(degree)	-0.120	-0.517	-0.426
	(3.593)	(4.161)	(12.25)
Non- reciprocated ties	5.416	13.66	12.04
	(76.27)	(83.25)	(266.1)
LCC	-0.719	-0.239	-0.377
	(3.690)	(4.576)	(12.03)
Interactions with year = 2011-2012			
Age at registration	-0.00614***	-0.00188	-0.00296***
	(0.00108)	(0.00824)	(0.000884)
Innovativeness	-0.000201***	-0.000607	-0.000260***
	(3.41e-05)	(0.000494)	(2.89e-05)
Degree	0.00189***	0.00165***	0.00168***
	(0.000164)	(0.000219)	(0.000141)
Ln(degree)	-0.253***	-0.280	-0.00784
	(0.0427)	(1.201)	(0.0280)
Non- reciprocated ties	-5.065***	-4.739**	-6.556***
	(0.414)	(1.563)	(0.382)
LCC	0.971	-0.00268	1.171
		(2.142)	
Variance (σ)			
year = 2007-2008	-0.0925	0.465	0.344
	(6.530)	(4.309)	(14.32)
year = 2011-2012	0.389***	0.0544	0.423***
	(0.0443)	(1.648)	(0.0365)
Thresholds			
Cutpoint 1	1.578***	1.914***	1.373***
	(0.0602)	(0.0632)	(0.0575)
N (user-years)	1,140,566	1,250,825	1,250,825

*Notes: Heterogeneous choice (oglm) models.Unstandardized coefficients. Standard errors in parentheses. ***: p<0.001, **:p<0.01, *:p<0.05*

Excluding observations with less than ten connections influences our estimates only slightly. The main effects are similar to the baseline results. Interactions for 2011-2012 show similar differences compared to the reference category. Differences between years 2007-2008 and 2009-2010, however, are not significant in this specification. Thus the spurious relationship between degree and the definition of early abandonment did not influence our substantive conclusions (Table 5).

Table 5.

Predictors of leaving the network early (further alternative specifications)

Variables	(4) only users with more than 10 connections	(5) innovativeness measured within one's own network	(6) innovativeness measured only by time
Main effects			
Age at registration	0.00418***	0.00183**	0.00335***
	(0.000715)	(0.000671)	(0.000670)
Innovativeness	0.000517***	-0.000455***	0.000231***
	(2.65e-05)	(2.83e-05)	(2.48e-05)
Degree	-0.000984***	-0.00161***	-0.00195***
	(0.000145)	(0.000121)	(0.000124)
Ln(degree)	-0.528***	-0.335***	-0.401***
	(0.0201)	(0.0130)	(0.0131)
Non- reciprocated ties	8.568***	4.619***	5.861***
	(0.360)	(0.275)	(0.277)
LCC	2.684***	1.084***	1.250***
	(0.0855)	(0.0572)	(0.0576)
year = 2007-2008	0.210	1.335	-0.279
	(4.478)	(2.167)	(0.153)
year = 2011-2012	0.0823	1.124	0.189
	(0.107)	(2.042)	(3.016)
Interactions with year = 2007-2008			
Age at registration	-0.0173	-0.00600	-0.0116***
	(0.0413)	(0.0114)	(0.00176)
Innovativeness	0.000127	-0.000515	5.68e-05
	(0.00203)	(0.00264)	(8.69e-05)
Degree	0.000699	0.00108	-0.00140**
	(0.00108)	(0.00146)	(0.000444)
Ln(degree)	-0.803	0.195	-0.263***
	(4.184)	(0.381)	(0.0469)
Non- reciprocated ties	18.49	-1.476	8.402
	(85.09)	(8.547)	(0)
LCC	-0.562	-0.956**	-0.567***
	(6.678)	(0.353)	(0.121)
Interactions with year = 2011-2012			
Age at registration	-0.000341	-0.000243	5.41e-05
	(0.000963)	(0.00330)	(0.00650)
Innovativeness	-0.000480***	0.000292	-0.000300*
	(3.27e-05)	(0.000333)	(0.000135)
Degree	0.00105***	0.00155***	0.00180***
	(0.000173)	(0.000185)	(0.000322)
Ln(degree)	0.0480	0.0601	-0.0969
	(0.0372)	(0.556)	(0.942)
Non- reciprocated ties	-8.057***	-4.646***	-5.323***
	(0.463)	(0.317)	(1.084)
LCC	0.0512	-0.0345	0.614
		(2.124)	(3.524)

Variance (σ)			
year = 2007-2008	0.389	-1.165	0.116*
	(3.144)	(2.718)	(0.0523)
year = 2011-2012	0.102*	-0.350	0.196
	(0.0427)	(2.023)	(1.890)
Thresholds			
Cutpoint 1	1.632***	2.132***	1.784***
	(0.0892)	(0.0603)	(0.0592)
N (user-years)	1,216,041	1,250,825	1,250,825

*Notes: Heterogeneous choice (oglm) models. Unstandardized coefficients. Standard errors in parentheses. ***: p<0.001, **:p<0.01, *:p<0.05*

Innovativeness is one of our key explanatory variables but it might also have different operationalizations. The conceptual problem here is that it is impossible to separate the contextual effects of the time of registration and the time spent on the network, as any one of these and the time of leave determines the other. Substantively, however, early registration is a good proxy of innovativeness, while the time spent on the network isn't. Furthermore, as we have argued, we have reasons to believe that the social mechanisms triggering early abandonment change over time: they are different in the period of a mature network, when a major competitor enters, and in the declining phase. The models presented above have confirmed the presence of these differences. A further complication arises from the likely presence of a life-cycle effect. As a bivariate analysis shows, new users have an increasing likelihood of early abandonment that peaks 300-500 days after registration. If they stay after this critical period, they become more committed. All this cautions us about the interpretation of our innovativeness variable. The fact that we use a relative innovativeness measure (date of registration compared to the date of registration of users of a similar age) somewhat moderates this problem, but does not eliminate it completely.

We tried to mitigate this problem in the following two ways. First, we created an alternative, network-based measure of innovativeness. This alternative measure was defined as the difference between the date of registration of the user and the average date of registration in his or her network. Also for this measure, higher numbers indicate more innovative behavior. Second, we simply used the date of registration compared to its average value (again, the higher number indicates more innovative behavior). On the one hand, we see that the network-based measure of innovativeness has an opposite effect compared to the original measure, indicating that in 2009-2010 those users were more likely to leave early, who registered later than their social ties (Table 5). This result casts doubt on the validity of H3 and the related H4. On the other hand, if we use the registration date as a measure, the results correspond to the original hypothesis: people, who registered earlier, tend to leave early (Table 5).

DISCUSSION

Since the early years of the millennium, online social networks have a salient impact on our lives. The goal of our research was to uncover individual and micro-structural mechanisms responsible for user actions that are the most important determinants of apparent shifts in the popularity of online social networks (OSNs).

In this paper, we were interested particularly in social capital related mechanisms that can explain the collapse of an OSN. We examined the Hungarian network, iWiW, which was one of the first OSNs in the world and the most popular one in Hungary until 2010, after which it lost its significance and was subsequently shut down. Our analysis of the anonymized database concentrated on users who left the OSN early and played a pivotal role in starting the cascade. We classified users as 'early leavers' if they left the site when more than 90% of their social connections were still active on the OSN.

We discussed that the emergence of new OSNs could have triggered a switch for key actors. However, due to the lack of data from other sites, we were unable to test this hypothesis. More importantly, we argued that the concept of social capital could help to explain early abandonment. Yet, there are different and contradicting aspects of social capital, that could have played a role. The most obvious one is the extent of relations, which corresponds to the quantity of accumulated social capital. Our results, which are robust across various specifications, indicate that the size of the ego-network prevents users from leaving the OSN early.

We also investigated whether closed or open structures are relevant aspects of social capital for hindering early abandonment. We found confirmation of the hypothesized mechanism that the information aspect of social capital inherent in open social relations is especially important. Actors who have benefited from structural holes in their network on iWiW were less likely to abandon the site early. This observation has a theoretical consequence considering the resilience of the network. For example, Garcia, Mavrodiev, and Schweitzer (2013) suggest that higher k-coreness of the network increases resilience. We found, however, that a highly clustered structure associated with higher k-coreness is less valuable from the individual's perspective and therefore increases the risk of a collapse cascade.

It is clear that multiple mechanisms are responsible for the decline of the OSN. We also tested whether innovativeness contributes to the early abandonment of the network. Based on the network literature on the diffusion of innovations, we predicted that the innovative users who boosted the popularity of the OSN were also responsible for the cascades of early abandonment, when they switched to new alternatives. We indeed found a significant

relationship with early abandonment, when we measured innovativeness by joining iWiW earlier than a typical member of the age group. This mechanism, however, is only of secondary importance behind social capital explanations. We found smaller effect sizes, and the result was also not robust across measurements. There might be different explanations behind the weaker effect of innovativeness. One is that innovative individuals use the old and a new network simultaneously for a longer period, therefore, they do actually join the alternative network first, but many of them also keep the old network for maintaining the connection to a distinct group of their friends.

We found a similar positive effect, when measuring innovativeness by the relative time of joining the network. However, the result turned to the opposite when the user's time of registration was compared to the average time of registration in the user's ego-network. It is important to emphasize that our social capital based explanation was valid throughout the whole examined period, although its magnitude changed. At the same time, our arguments considering innovativeness lose their validity in the years of decline. This could possibly be because our definition of 'early abandonment' does not characterize key actors in the last years. The key actors left already, and their followers were more likely to leave than users who could be characterized as remaining key actors in their network.

All things considered, we were able to draw important conclusions about social capital related mechanisms behind the collapse of an OSN. We have to note, however, that while our conclusions are based on a complete set of data with regard to connections, the data is not rich in depth: we do not have more information on individual background variables, the strength of ties, or even more importantly, on the use of alternative OSNs. A possible known limitation of the analysis is that we miss those users, who deleted their profiles completely. Fortunately, such cases were extremely rare before 2013. We do not have data on the intensity of user activity either, for example, on the frequency of logins and interactions with others. Only the very last login date to the network is saved. A simple login is a low cost activity and the results might be different for activities requiring higher intensity. Further research could investigate this or could justify our claims by studying other radical shifts in the OSN world.

Our study has implications not just for the study of online social networks, but for the analysis of leaving social groups and social contexts in general. Other studies, particularly in the organizational context, identified social capital related explanations for leaving or for leaving intention similarly (Dess and Shaw 2001; Kratzer and Takács 2007; Soltis et al. 2013). They also highlighted, however, that leaving an organization or an organizational unit cannot be analyzed independently from the availability of outside options.

The results are relevant also for networks operators. For them, it is crucial to identify the users who could trigger a cascade of abandonment. In this sense our conclusion is clear: in the case of iWiW, the avalanche did not start from the core. Degree has a negative effect on early abandonment, and being an early member is associated with a somewhat higher probability of leaving the network before one's friends only after controlling for the size of the user's network.

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