See you on Facebook: the effect of social networking on human interaction

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23 December 2010

See you on Facebook: the effect of social networking on human interaction

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December 2010

Abstract

This paper proposes an evolutionary framework to explore the dynamics of social interaction in an environment characterized by online networking and increasing pressure on time. The model shows how time pressure encourages the choice to develop social interactions also through online networking instead of relying exclusively on face to face encounters.

Our findings suggest that the joint influence exerted by the reduction in leisure time and the new opportunities of participation offered by web-mediated communication may progressively lead a growing share of the population to adopt networking sites as an indispensable environment for the development of interpersonal relationships.

Keywords: internet, computer-mediated communication, social networking, online networks, Facebook, human interaction, social capital.

JEL Codes: O33, Z13

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1 Introduction

While we were writing this introduction, Facebook was working on plans for their 500 million user celebration, which took place in July 2010. This means that, if the website were granted a strip of land, it would be the world's third largest country by population, two-thirds bigger than the U.S.

Today, as we are drawing our conclusions, Facebook founder Mark Zuckerberg has just been named Time Person of the Year 2010, "For connecting more than half a billion people and mapping the social relations among them; for creating a new system of exchanging information; and for changing how we all live our lives"[4].

Facebook is the tip of the social networking iceberg. Other sites like Twitter, Flickr, and MySpace previously experienced a similar (even if more limited) growth. This is not the only reason why economics, political science, and sociology (in a strictly alphabetical order) should deal with the advent of online networking. According to Facebook's official statistics, 50% of active users log on in any given day. The average user has about 130 "friends", and total users spend over 700 billion minutes per month on the platform. There are over 900 million objects (pages, groups, events and community pages) that people interact with, and the average user is connected to 80 of them. Each one of these objects is conceived as a place for social interaction where people can share their views and plan actual meetings (e.g. attending a concert). More than 200 million active users interact with their Facebook friends through a mobile device. People that use Facebook on their mobiles are twice as active on Facebook than non-mobile users[5]. These numbers suggest that social interactions are undergoing a true revolution. The change is hitting public life and the economy as well. Think for example of how Mr. Obama used social networking sites (SNSs) to organize his supporters and win the presidential race, or of the major change online review systems like Tripadvisor brought about in vacation habits.

With respect to face to face interactions, social networking presents a number of easy to guess shortcomings, but it certainly exhibits two major advantages as well: it is less time intensive and less expensive too. Economic development brings about increasing pressure on time, which in turn causes a substitution of time intensive social activities - like dining with friends - with time saving private ones like watching television (Antoci, Sacco and Vanin, 2005, 2007, Antoci, Sabatini and Sodini, 2010a, 2010b). Internet-mediated interaction can potentially mitigate, or even reverse, such a worrying trend. SNSs like Facebook and Twitter allow users to stay in touch with friends in their spare time, while sitting at a desk during the work day or while waiting for the train.

However, social networking is a surprisingly neglected topic in the literature. To date, the social science debate on SNSs seems to be constrained to the fields of law and applied psychology, mostly pointing at "limited-scope" issues like privacy risks and the effects of the

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[4] Lev Grossman, Mark Zuckerberg Person of the Year 2010, published online on Wednesday, Dec. 15, 2010, Time, http://www.time.com/time/specials/packages/article/0,28804,2036683_2037183,00.html.

[5] Facebook official statistics, retrieved online on November 30, 2010, at http://www.facebook.com/press/info.php?statistics.

internet on teenagers' mental health. Until now, empirical research has indeed been hampered by the lack of data. The social networking revolution is too recent: it is still very difficult to carry out reliable longitudinal analyses properly taking into account endogeneity problems. However, during the wait for suitable data, there is an urgent need to define a theoretical framework to investigate how the combined effect of online networking and time pressure is going to change social interaction.

This paper proposes an evolutionary framework to explore the dynamics of social interaction in an environment characterized by online networking and increasing pressure on time. We assume that, in each instant of time t, the share $x(t) \in [0,1]$ of agents embrace a social networking strategy *SN*, i.e. their social participation relies both on online networks and face to face interaction. The remaining share of the population $1-x(t)$ adopts a face to face strategy *FF*: they do not interact online and thus develop all their relationships through face to face encounters. The payoff of the *FF* strategy, Π^{FF}, depends on $x(t)$ and on the share of time devoted to social interaction, p, which will be treated as an exogenous parameter in our analysis. The payoff for the individuals playing SN, Π^{SN}, depends on an additional variable $K_N(t)$, expressing the wealth of ties forming online networks at time t or, in other words, the internet's stock of social capital. In this paper, we focus solely on the internet's social capital, instead of also accounting for the stock of ties accumulated through face to face interactions. This strong assumption is motivated by two main reasons. First, there is a significant difference in the velocity of accumulation of the two types of stock. Online ties can be formed and deepened much more rapidly than face to face interactions. Second, given the extraordinary velocity with which the social networking revolution is taking off, our model is intended to address a rather limited lapse of time.

The analysis in the paper shows how time pressure biases the evolution of the two shares $x(t)$ and $1-x(t)$ (respectively playing *SN* and *FF*), through changes in the time p available for social participation. Our findings suggest that the joint influence exerted by the reduction in leisure time and the new opportunities for participation offered by SNSs may progressively lead a growing share of the population to embrace the *SN* strategy (i.e. it may lead society to a steady state in which $x(t)=1$). This perspective is less worrying than it may seem at a first glance. "Pure" face to face relationships are not necessarily more rewarding than mixed interactions which rely both on actual encounters and continuous, less time consuming and less expensive web-mediated communication. On the contrary, under certain conditions, social networking may work as an indispensable instrument for preserving social interaction from the growing pressure on time and the deterioration in social life.

The reminder of the paper is organized as follows: in the next section we provide some definitions. In section three we critically review the related literature. In section four we present our assumptions and the model. In section five we analyze and comment on the model. The paper is closed by a discussion of results and a few concluding remarks.

2 Definitions

Since social networking is a relatively new topic in the literature, some definitions are needed. First, due to the common wisdom widespread among non-internet users, according to which the internet is mostly a place to find a partner a distinction is needed between social networking sites (SNSs) and dating websites. Dating websites allow individuals, couples and groups to make contact and communicate with each other over the internet, usually with the objective of developing a personal romantic or sexual relationship. A concise definition of SNSs is provided by boyd and Ellison (2007): "We define social networking sites as web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system". The first social networking site was launched in 1997 and there are currently hundreds of SNSs across the globe, supporting a spectrum of practices, interests and users (Steinfield et al. 2008). What makes SNSs unique is not that they allow individuals to meet strangers, but rather that they enable users to make visible, articulate, and develop their social networks. This can result in connections between individuals that would not otherwise be made. However, for most people, that is often not the goal., and these meetings frequently materialize "latent ties" (Haythornthwaite 2005) between people who share some offline connection (for example a mutual friend or common cultural interests). On SNSs, participants are not necessarily "networking" or looking to meet new people. Instead, they are primarily communicating with people who are already a part of their extended social network (boyd and Ellison 2007, Ellison et al. 2007). Ellison, Steinfield, and Lampe (2007) suggest that Facebook is used to maintain existing offline connections, as opposed to meeting new people. "These relationships may be weak ties, but typically there is some common offline element among individuals who friend one another" (boyd and Ellison 2007), such as, for example, a shared class at school, a hobby, support for a football club, or a professional experience. From this point of view, the potential of SNSs in fostering the development of bridging ties, or what the literature has labelled as "bridging social capital", is rather evident. Bridging social capital can be defined as the sum of horizontal ties shaping heterogeneous groups of people. The term "bridging" refers to the ability of such ties to create horizontal "bridges" connecting sectors or places of society that otherwise would have never come into contact (Granovetter 1985, Gittel and Vidal 1998, Sabatini 2008).

However, it is undeniable that SNSs also offer extraordinary opportunities to establish connections between previously unknown people, coming from different socio-economic backgrounds and even from distant geographic areas. For example, besides its ability to help users stay in touch with kin and friends, Facebook is a place for citizens to come into contact with their political representatives, for newspaper readers to interact with their favourite journalists, for students to approach professors, for researchers to exchange ideas and start new collaborations. From this point of view, social networking platforms can be viewed as a powerful source of what the literature has labelled "linking social capital". This term describes vertical ties connecting individuals, or the groups they belong to, to people or groups in positions of political or financial power. According to Putnam et al. (1993), this kind of tie is critical for leveraging resources, ideas and information beyond normal community linkages.

In the lexis of the evolutionary framework we adopt in this paper, the definitions briefly outlined above suggest that SNSs' users develop their social relationships through a complex strategy, which includes *both* offline and online interactions. In most cases, online interactions are aimed at reinforcing and developing existing ties. Incidentally, networking platforms are a fertile ground for coming into contact with strangers and developing new relationships, thereby expanding users' personal networks of contacts. This strategy is "opposed" to that of non-SNSs users, whose social life takes place exclusively in the context of face to face interactions.

3 Related literature

The main goal of this work is to improve our understanding of how the online social networking revolution may change social life. Most of the previous studies on this topic are cross-sectional, survey-based empirical investigations published in information science and communication journals. It is noteworthy that, to date, only two peer-reviewed scholarly journals devoted a special issue to social networking. They are: 1) The *Journal of Computer-Mediated Communication*, a web-based journal, listed by the ISI Journal Citation Report (JCR) in the fields of Communication, Information science and Library science[6]; 2) and The *Journal of Applied Developmental Psychology*, listed by the ISI JCR in the field of Developmental psychology[7]. A number of studies are co-authored by scholars and non-academic researchers employed by SNSs (see for example the empirical investigations on Facebook carried out by Burke, Marlow and Lento 2009, 2010). These works are often presented at conferences, but not systematically submitted to scholarly journals. Business studies sporadically address the topic in reference to the role of SNSs in fostering job-matching processes (Parker 2008) and in the development of marketing strategies for new products and services (Felzenstein and Gimmon 2009). In economics, until now the topic has been neglected or even ignored. As of this writing, a keyword search for strings like "social networking sites", "online networking", or "Facebook" in EconLit, the most comprehensive database of published articles in economics, gives no results. Searching the same strings in RePEc, the largest online database of unpublished works in economics, returns a small bunch of papers, mostly authored by anthropologists and sociologists.

The two conflicting hypotheses standing from the narrow literature mentioned above are: 1) SNSs reduce face to face interaction and foster isolation. 2) SNSs support human interactions and well-being.

3.1 Online networking hampers social interaction

Early studies on the social effects of the internet shared the fear of a progressive reduction in social interaction. Theoretically, three main arguments nurture this concern.

First, the more time people spend using the internet during leisure time, the more time has to be detracted from social activities like communicating with friends, neighbours and family members (Nie et al. 2002, Wellman et al. 2006). This argument recalls the hypotheses advanced by recent behavioural studies analyzing the effects of television on relational goods and happiness (Bruni and Stanca 2006, 2008, Frey et al. 2007, Robinson and Martin 2008). Indeed, sectional studies conducted before the widespread diffusion of social networking found negative associations between internet use and face to face interaction (Nie 2001, Nie

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[6]More precisely, the *Journal of Computer-Mediated Communication* devoted a "special theme section" to social networking (boyd and Ellison, 2007) in its Volume 13, Issue 1, in 2007.

[7]*Journal of Applied Developmental Psychology*, "Social Networking on the Internet - Developmental Implications". Volume 29, Issue 6, pages 415-434.

et al. 2002, Gershuny 2003). Wellman et al. (2006) note that internet usage may sometimes interfere with communication in the home, creating a "post-familial family" where family members spend time interacting with computers rather than with each other. In fact, an earlier study by Kraut et al. (1998) found that heavier internet use was associated with various measures of loneliness, depression and stress. The authors argued that this was because weaker ties generated online were replacing stronger offline ties with family and friends. However, in a follow-up study, Kraut et al. (2002) found that, when examined over a longer period of time, internet use was no longer associated with decreased communication and involvement with family (and the associated measures of loneliness and depression). At the theoretical level, the risk that technology-intensive consumption can stimulate a process of substitution of relational activities with "private" ones has been analyzed in Antoci, Sabatini and Sodini (2010a, 2010b). In our view, this risk basically refers to forms of non-interactive technology-intensive consumption, like dvd players and video game consoles.

The literature advancing "pessimistic" hypotheses on the relational effects of the internet dates back to just shortly before the explosion of online networking. These studies could not differentiate between pure entertainment and social activities. At that time, using the internet was in fact predominantly an individual activity like watching TV or reading newspapers. Today, the use of the internet is strongly related to being connected to social networking sites, which in turn brings about engagement in social activities. According to data on the U.S. provided by the Pew Internet & American Life Project, as of September 2009 nearly three quarters (73%) of online teens (aged 12-17) and an equal number (72%) of young adults (18-29) use social network sites[8].

This evolution makes any comparison between the internet and TV simply anachronistic. The finding of two studies on the relationship between internet, television and social interaction further point to the dissimilarity of internet use and watching tv. Drawing on Swiss panel data, Franzen (2003) shows that the time devoted to internet usage replaces time that would otherwise be spent watching television, rather than detracting from social interaction. An identical result is obtained by Anderson (2008), drawing on *eLiving*, a panel conducted in six European countries in 2001 and 2002.

Another argument relies on the fact that the internet allows users to conduct many daily transactions such as shopping or banking online from home (Nie et al. 2002, Franzen 2003). The supporters of this argument suggest that to shop and carry out a number of tasks without leaving home may reduce face to face interaction. A straightforward objection is that transactions and other commissions often do not have particular relational implications. By contrast, they distract time from relational activities. If we spend part of the day dealing with a bank or a public administration office, then we may be constrained to work more to make up for the hours lost, and to give up the intention of meeting friends. Obtaining a birth certificate or a bank statement online in just a few seconds from home allows us to gain more time for leisure and social participation.

A more intriguing argument relies on the concept of "community without propinquity" (Weber 1963) and on the earlier theories of the Chicago School of Sociology. In a famous paper, Wirth (1938) claimed that a heterogeneous urban environment would be characteristic

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[8] Data can be retrieved online on the Pew Internet & American Life Project web site at the address http://www.pewinternet.org/. See in particular the reports by Lenhart et al., 2010a, 2010b.

of the absence of "intimate personal acquaintanceship" and would result in the "segmentation of human relations" into those that were "largely anonymous, superficial, and transitory" (Wirth 1938, p . 1). This argument can be easily applied to the internet, which seems to have the potential to fragment local communities into new virtual realities of shared interest that may negate the necessity (or even the desirability) of face to face encounters. The "anonymization hypothesis", however, has been challenged by results from studies specifically targeted at verifying the effects of online networking on communities living in a precise geographic location (e.g. a city area or suburb). The seminal paper in this field is probably the pioneer study by Hampton and Wellman (2003). Drawing on survey and ethnographic data from a "wired suburb" of Toronto, the authors find that high-speed, always-on access to the internet, coupled with a local online discussion group, transforms and enhances neighbouring. The internet especially supports increased contacts with weaker ties, without bringing about a deterioration of strong ties. In the authors' words, "Not only the internet supported neighbouring, it also facilitated discussion and mobilization around local issues" (Hampton and Wellman 2003, p . 277). A similar study by Kavanaugh et al. (2005) on the Blacksburg Electronic Village concludes that computer-mediated interactions have positive effects on community interaction, involvement, and social capital.

3.2 Online networking fosters social interaction

Findings from the latest wave of studies (i.e. carried out between 2006 and 2010) on the relational effects of social networking unanimously converge on the claim that online networks support the consolidation and development of existing ties.

The main reason for which these works appear to be more reliable than those briefly presented in the previous section is that they were conducted *after* the explosion of online networking. Thus, they are specifically targeted at assessing the implications of SNSs. From a methodological point of view, it is remarkable that studies on Facebook often rely on server log data provided by the platform itself, which provides large samples, higher representativeness, objective information on what people really do on the platform, allowing for the distinction between social activities and individual pastimes like taking quizzes. Furthermore, some researchers have been able to carry out the first longitudinal analyses in the field (see for example Steinfield et al. 2008).

According to this strand of the literature, SNSs support the strengthening of bonding and bridging social capital (Valkenburg et al. 2006, Ellison et al. 2007, Steinfield et al. 2008, Gilbert et al. 2009, Burke et al. 2009), allow the crystallization of weak or latent ties that might otherwise remain ephemeral (Haythornthwaite 2005, Ellison et al. 2007), support teenagers' self-esteem - encouraging them to relate to their peers (Ellison et al. 2007, Steinfield et al. 2008), stimulate social learning (Burke et al. 2010), enhance social trust, civic participation and political engagement (Valenzuela et al. 2009), facilitate the creation of electronic networks of practice (Vasko and Faray 2005, Landqvist and Teigland 2010, Matzat 2010), and help the promotion of collective actions to the pursuit of shared goals (Landqvist and Teigland 2010).

Drawing on survey data from a random sample of 800 Michigan State University undergraduate students, Ellison et al. (2007) find that certain kinds of Facebook use can help students accumulate and maintain bridging social capital. The authors suspect that the social network serves to lower the barriers to participation so that students who might otherwise shy away from initiating communication with others are encouraged to do so through the Facebook infrastructure. In the authors' words, "Highly engaged users are using Facebook to crystallize relationships that might otherwise remain ephemeral" (2007). As argued by Haythornthwaite (2005), social media create "latent tie connectivity among group members that provides the technical means for activating weak ties" (*p* . 125). Latent ties are those social network ties that are "technically possible but not activated socially" (*p* . 137). According to Ellison et al. (2007), "Facebook might make it easier to convert latent ties into weak ties, in that the site provides personal information about others, makes visible one's connections to a wide range of individuals, and enables students to identify those who might be useful in some capacity, thus providing the motivation to activate a latent tie". Ellison et al. (2007) also demonstrate a correlation between bridging social capital and subjective well-being measures: less intense Facebook users report lower levels of life-satisfaction, self-esteem and bridging social capital. As an explanation, the authors suggest that Facebook use may be helping to overcome barriers faced by students who have low satisfaction and low self-esteem.

Steinfield et al. (2008) analyzed panel data from two surveys on Facebook users conducted a year apart at a large U.S. university. Intensity of Facebook use in year one strongly predicted bridging social capital outcomes in year two, even after controlling for measures of self-esteem and satisfaction with life. The authors suggest that "Facebook affordances help reduce barriers that lower self-esteem students might experience in forming the kinds of large, heterogeneous networks that are sources of bridging social capital". This study claims that SNSs may be particularly helpful in assisting students during the transition from school to college or work. In most cases, these transitions bring about socially disruptive changes in individuals' lives. Routledge and von Ambsberg (2005) indeed attribute the cooling and disruption of social ties to the rise in people's mobility. The authors suggest that, at the macro level, this process may result in the progressive erosion of the stock of social capital. Taking into account the results from the latest studies on Facebook users, it is possible to argue that SNSs can work as an antidote slackening the mobility-driven erosion process. Online networking indeed seems to support the maintenance of relationships among individuals entering college, moving between residences, graduating and entering the professional workforce (Steinfield et al. 2008, Subrahmanyam et al. 2008).

Using data from a random web survey of 2,603 college students in Texas, Valenzuela et al. (2008) find moderate, positive relationships between intensity of Facebook use and students' life satisfaction, social trust, civic participation and political engagement. After controlling for a series of variables, the authors claim that their results show that the association between online networking and social capital cannot be considered spurious. Despite the interesting results and convincing interpretations, the empirical analyses carried out by Ellison et al. (2007), Steinfield et al. (2008), and Valenzuela et al. (2008) share a common shortcoming: they all refer to localized communities, like the students of a specific college. An interesting development in this sense is provided by two recent studies based on the matching between survey and server log data provided by Facebook (Burke et al. 2009, 2010). The cooperation with the biggest social network has allowed researchers to investigate the behaviour of largest and more representative samples.

Drawing on survey data from a sample of 1,193 participants recruited via an "ad" on

Facebook targeted at English-speaking adults, Burke et al. (2009) find that overall SNS activity, particularly friend count, is positively correlated with bonding and bridging social capital. It is also negatively correlated with loneliness. Content production (e.g. writing notes and sharing photos) is strongly associated with increases in bridging social capital. Using server log data from approximately 140,000 newcomers who joined Facebook in March 2008, Burke et al. (2010) find evidence of social learning: newcomers who see their friends contributing go on to share more content themselves.

In this paper we explicitly model the hypothesis claimed in this section that online networking is a mean for nurturing and articulating existing ties, as well as a fertile ground for the development of new ones. In our model, a share of the population develops its social life both through face to face encounters and online contacts via SNSs like Facebook. Drawing on a review of descriptive data from the major U.S. survey sources (e.g. the Pew Internet & American Life Project), we assume that a decreasing but significant part of the population remains unfamiliar with online networking. These agents develop their social participation only by meeting their friends and acquaintances in person.

4 The model

We model an economy composed by a continuum (of measure 1) of identical individuals. In each instant of time they choose how to allocate their leisure time, p, which is exogenously given, between two kinds of social interaction, taking the form of the *FF* and the *SN* strategies briefly outlined in the introduction. With the *FF* strategy, individuals develop their social relationships through face to face encounters. In the *SN* strategy, social participation takes place both through face to face meetings and online networking. We assume that the technology for social networking is available for all agents. In principle, individuals can thus simultaneously interact with multiple agents (theoretically, even with all of the agents in the population).

The payoff of the *FF* strategy, Π^{FF}, depends on $x(t)$ and on the share of time devoted to social interaction, p, $\Pi^{FF} := \Pi^{FF}(x,p)$. The payoff of the *SN* strategy, Π^{SN}, depends on the share of the population adopting it, $x(t)$, on the time agents devote to social participation, p, and on the wealth of ties - or, in other words, the stock of social capital - of online networks at time *t*, $K_N(t)$: $\Pi^{SN} := \Pi^{SN}(K_N, x, p).$

The stock $K_N(t)$ is a public good, in that it potentially benefits whoever is connected to the Web and adopts the *SN* strategy. It potentially includes bonding ties with close people as well as the bridging and linking ties briefly defined above.

We assume that the payoff Π^{FF} decreases as the share of the population adopting the *SN* strategy grows. On the other hand, we account for the claim that online networks are used mainly to maintain existing offline relationships (boyd and Ellison 2007), to crystallize weak ties (Ellison et al. 2007) and to activate latent ties (Haythornthwaite 2005), through the assumption that the payoff Π^{SN} increases as K_N, i.e. the stock of the internet's social capital, grows. In other words, the more the number of relatives and friends who join SNSs grows, the higher the return of joining those networks will be as well. Formally, we assume $\Pi^{SN}(K_N, x, p)$ and $\Pi^{FF}(x,p)$ to be differentiable functions satisfying the following conditions:

$$\frac{\partial \Pi^{SN}(K_N, x, p)}{\partial x} > 0 > \frac{\partial \Pi^{FF}(x, p)}{\partial x}$$

$$\frac{\partial \Pi^{SN}(K_N, x, p)}{\partial K_N} > 0$$

An increase in the share x of the population adopting the *SN* strategy positively affects the payoff Π^{SN} and negatively affects the payoff Π^{FF}: the more our friends join Facebook, the higher the utility of subscribing to the platform will be as well. On the other hand, being outside of the network (i.e. continuing to play the *FF* strategy) may imply an increasing relational cost. Think for example of an *FF*-playing teenager whose classmates join Facebook. Not following them into the network may lead to the cooling of some relationships as well as to the exclusion from new ones established through the activation of latent ties.

Since the comparative advantage of the *SN* strategy is partly driven by the pressure on time, we assume that, when the time p available for social participation grows, the payoff Π^{FF} for agents playing the *FF* strategy increases more than the payoff Π^{SN} obtained by *SN* players. If agents are forced to be deeply immersed in their professional activities, the ability to take care of human relationships in spare moments (e.g., while on the train, or at home before going to sleep) becomes a precious means for the preservation of social life. *SN* can thus be interpreted also as a "defensive" strategy that individuals adopt to protect their social life from growing pressure on time. The more the time available for social participation p declines, the more a "defensive" reaction is needed, making the *SN* strategy comparatively more profitable. By contrast, if the time p for leisure grows, then there is a relaxation in the need for defensive behaviours, which makes the *FF* strategy comparatively more profitable. Formally, this assumption can be expressed as follows:

$$\frac{\partial \Pi^{FF}(x, p)}{\partial p} > \frac{\partial \Pi^{SN}(K_N, x, p)}{\partial p} \qquad (1)$$

We follow an evolutionary game approach and assume that the time derivative of $x(t)$, $\dot{x} = dx/dt$, is given by:

$$\dot{x} = F\left[x, \Pi^{SN}(K_N, x, p) - \Pi^{FF}(x, p)\right]$$

where F is a differentiable function for every $x \in (0,1)$ and $K_N,\ p \geq 0$. Furthermore, F satisfies the following assumptions:

a) It is strictly increasing in $\Pi^{SN} - \Pi^{FF}$ (i.e. $F_2 > 0$) for every $x \in (0,1)$ ("payoff monotonicity" assumption, see for example Weibull 1995);

b) $F(x,0) = 0$ for every $x(t) \in [0,1]$, i.e. $\mathbf{x}$ does not change when the payoffs of the two strategies are the same.

c) Moreover, as usual, we assume that the share $x(t)$ of agents adopting the *SN* strategy cannot become negative or bigger than 1 (i.e. $0 \le x(t) \le 1$ always holds); in particular, we assume that F satisfies the following conditions:

$$F\left[0, \Pi^{SN}(K_N, 0, p) - \Pi^{FF}(0, p)\right] = 0 \quad \text{if} \quad \Pi^{SN}(K_N, 0, p) - \Pi^{FF}(0, p) \le 0$$
$$F\left[0, \Pi^{SN}(K_N, 0, p) - \Pi^{FF}(0, p)\right] > 0 \quad \text{if} \quad \Pi^{SN}(K_N, 0, p) - \Pi^{FF}(0, p) > 0 \tag{2}$$

and

$$F\left[1, \Pi^{SN}(K_N, 1, p) - \Pi^{FF}(1, p)\right] = 0 \quad \text{if} \quad \Pi^{SN}(K_N, 1, p) - \Pi^{FF}(1, p) \ge 0$$
$$F\left[1, \Pi^{SN}(K_N, 1, p) - \Pi^{FF}(1, p)\right] < 0 \quad \text{if} \quad \Pi^{SN}(K_N, 1, p) - \Pi^{FF}(1, p) < 0 \tag{3}$$

The time evolution of the internet's stock of social capital is path dependent and positively influenced by the size x of the population adopting the *SN* strategy. An increase in the wealth of ties of online networks at time t will foster the accumulation of social capital K_N. Furthermore, since human relations developed online need care to be preserved just like "traditional" ties, we introduce a positive social capital depreciation rate to account for possible cooling over time.

The time evolution of K_N is thus described by the equation:

$$\dot{K}_N = \beta x - \gamma K_N$$

where β is the elasticity of the time evolution of the stock of online social capital with respect to the share x of the population adopting the *SN* strategy and γ is the depreciation rate of K_N.

Notice that the maximum sustainable level of the stock K_N is $K_N = \frac{\beta}{\gamma}$, which can be reached only if the whole population chooses the *SN* strategy (i.e. $x = 1$). We assume that, in this context ($x = 1$ and $K_N = \frac{\beta}{\gamma}$), the payoff Π^{SN} is higher than the payoff Π^{FF}. On the other hand, if every individual adopts the *FF* strategy (i.e. $x = 0$) and $K_N = 0$, the payoff of SN is lower than that of *FF* (whatever the value of p is):

$$\Pi^{SN}\left(\frac{\beta}{\gamma}, 1, p\right) > \Pi^{FF}(1, p)$$
$$\Pi^{SN}(0, 0, p) < \Pi^{FF}(0, p)$$

Thus, the system to be analyzed is:

$$\dot{K}_N = \beta x - \gamma K_N \tag{6}$$

$$\dot{x} = F\left[x, \Pi^{SN}(K_N, x, p) - \Pi^{FF}(x, p)\right] \tag{7}$$

which is defined in the set:

$$S := \left\{(K_N, x) \in R^2 \middle| K_N \geq 0, 1 \geq x \geq 0\right\}$$

5 Analysis of the model

The following propositions highlight the qualitative features of the dynamics of the model.

Proposition 1 *The dynamic system (6)-(7) always admits three stationary states, i.e. three states* (K_N, x) *where* $\dot{K}_N = \dot{x} = 0$ *(see Fig.1):*

$$(K_N, x) = (0,0), (\frac{\beta}{\gamma},1), (K_N^*, x^*)$$

where $\frac{\beta}{\gamma} > K_N^* > 0$ and $1 > x^* > 0$.

Proof. $\dot{K}_N = 0$ holds along the straight line $x = \frac{\gamma}{\beta} K_N$ while $\dot{x} = 0$ in the states (K_N, x) satisfying the equation:

$$\Delta\Pi(K_N, x, p) := \Pi^{SN}(K_N, x, p) - \Pi^{FF}(x, p) = 0 \tag{8}$$

or in the states $(K_N, 0)$ and $(K_N, 1)$ satisfying respectively the conditions (see (2) and (3)):

$$\Pi^{SN}(K_N, 0, p) - \Pi^{FF}(0, p) \leq 0$$
$$\Pi^{SN}(K_N, 1, p) - \Pi^{FF}(1, p) \geq 0$$

So, under conditions (4)-(5), the states $(K_N, x) = (0,0)$, $(\frac{\beta}{\gamma},1)$ are stationary states.

By the implicit function theorem we have that equation (8) defines a function $x = g(K_N)$ such that:

$$g'(K_N) = -\frac{\frac{\partial \Delta\Pi}{\partial K_N}}{\frac{\partial \Delta\Pi}{\partial x}} = -\frac{\frac{\partial \Pi^{SN}}{\partial K_N}}{\frac{\partial \Pi^{SN}}{\partial x} - \frac{\partial \Pi^{FF}}{\partial x}} < 0$$

Therefore the curves $x = \frac{\gamma}{\beta} K_N$ and $x = g(K_N)$ can intersect at most once. It is easy to check that, under the assumptions (4)-(5), these curves always admit an intersection point in the interior of the set S and, consequently, an interior stationary state (K_N^*, x^*) with $\frac{\beta}{\gamma} > K_N^*$ > 0 and $1 > x^* > 0$ always exists.

Proposition 2 *The interior stationary state (K_N^*, x^*) is always a saddle point, while both the stationary states $(\frac{\beta}{\gamma}, 1)$ and $(0,0)$ are locally attractive. Each trajectory of the dynamic system (6)-(7) approaches one of these stationary states.*

Proof. Notice that $\dot{K}_N > 0$ for $x > \frac{\gamma}{\beta} K_N$ and $\dot{K}_N < 0$ for $x < \frac{\gamma}{\beta} K_N$; furthermore, $\dot{x} > 0$ holds above the graph of the function $x = g(K_N)$ (see the proof of Proposition 1) and $\dot{x} < 0$ below it. This implies that both the stationary states $(\frac{\beta}{\gamma}, 1)$ and $(0,0)$ are locally attractive (see Fig.1).

The stability properties of the interior stationary state (K_N^*, x^*) can be easily checked by writing the jacobian matrix of the dynamic system (6)-(7) evaluated at (K_N^*, x^*) (by assumption (b), $F_1(x,0) = 0$ always holds):

$$J(K_N^*, x^*) = \begin{pmatrix} -\gamma & \beta \\ F_2 \cdot \frac{\partial \Pi^{SN}}{\partial K_N} & F_2 \cdot \left(\frac{\partial \Pi^{SN}}{\partial x} - \frac{\partial \Pi^{FF}}{\partial x} \right) \end{pmatrix}$$

This matrix has a strictly negative determinant and consequently the stationary state (K_N^*, x^*) is a hyperbolic saddle.

(K_N^*, x^*) being a saddle, limit cycles cannot exist around it; therefore, by the Poincare-Bendixson theorem, each trajectory approaches a stationary state.

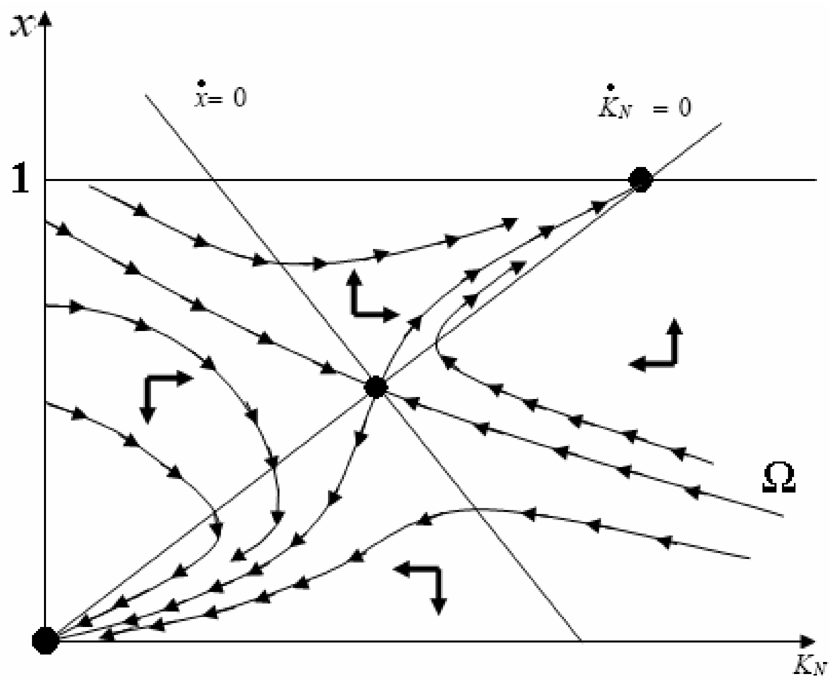

Figure 1, Phase plane of the dynamic system (6)-(7)

Proposition 3 *The size of the basin of attraction of the stationary state* $(\frac{\beta}{\gamma},1)$ *increases if the value of the parameter* p *increases (see Fig. 2).*

Proof. The basins of attraction of the stationary states $(0,0)$ and $(\frac{\beta}{\gamma},1)$ are separated by the stable manifold of the stationary state (K_N^*,x^*) (see Fig.1). This separatrix is the graph Ω of a decreasing function of K_N with slope $\frac{dx}{dK_N}=\frac{\dot{x}}{\dot{K}_N}<0$ if $\dot{K}_N \neq 0$ (in particular, on the left of (K_N^*,x^*) we have $\dot{x}<0$ and $\dot{K}_N>0$, on the right $\dot{x}>0$ and $\dot{K}_N<0$). Let us consider two different values of p, p_1 and p_2, with $p_1>p_2$, and indicate by $\Omega_{p=p_1}$ and $\Omega_{p=p_2}$ the separatrices corresponding, respectively, to the values $p=p_1$ and $p=p_2$.

Notice that, if p increases (ceteris paribus), the value of $\dot{x}$ decreases (i.e. $\frac{\partial \dot{x}}{\partial p}<0$) by assumption (1) while that of $\dot{K}_N$ remains constant. It follows that, setting $p=p_2$, the locus $\Omega_{p=p_1}$ is crossed from the left to the right by the trajectories of the system (6)-(7) with $p=p_2$. This implies that the basin of attraction of $(\frac{\beta}{\gamma},1)$ is larger for $p=p_2$ than for $p=p_2$, that is, $\Omega_{p=p_2}$ lies on the left of $\Omega_{p=p_1}$.

The same shift in the position of Ω can be caused by a increase in the elasticity β of the accumulation of social capital with respect to the share x of agents playing *SN*, or by a reduction in the depreciation rate γ of K_N. Both these parameters mainly depend on a variety of (mainly technological) factors. First, the design and dimension of the prevalent online networks are likely to play a relevant role.

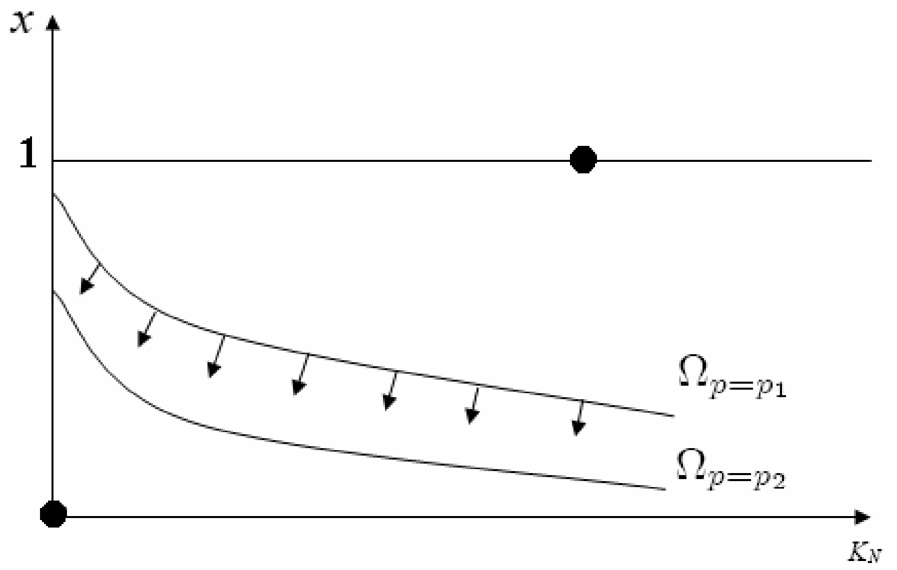

Figure 2: Shift of the stable manifold when p varies

At the dawn of the social networking era, the elasticity β probably had a "low" value. At that time, the social capital of the Web was "fragmented" in a big number of small networks, within which newcomers had a limited probability of meeting all of their *SN* playing actual friends. On the other hand, people who joined just one network were not necessarily able to connect with members of other platforms.

If newcomers do not connect each other, then the increase in their number is likely to exert a limited influence on the overall wealth of ties of the Web. This implies a low value of the elasticity β. By contrast, if newcomers are attracted by a small number of "big" networks, or even by just one enormous platform like Facebook, they are more likely to interact with each other and to re-connect with a major share of their actual, old-SN-player friends. An increase in the share x of the population adopting the SN strategy will thus exert a major influence on the Web's social capital, i.e. the elasticity β has a "high" value.

In this framework, the "explosion" in the number of subscribers that Facebook and a few other sites experienced in the last two years can be viewed as a true turning point. Before the Facebook era, a newcomer could choose among at least 100 major online networks counting more than 100,000 subscribers[9]. The risk of meeting just a very limited part of one's circle of friends on the Web was very high, so that the Web could hardly be seen as an effective, alternative, way to take care of the relational sphere of an individual's life. Now that Facebook counts more than 500 million users, the probability of finding a big and growing part of one's actual network of relations on the platform is higher. Newcomers will be attracted by just one or two major sites (probably Facebook and Twitter) where they will be able to find their old friends and meet a significant amount of new ones. So, the stock of the Web's social capital will benefit from an increase in the share x of *SN* players to a higher extent. Second, since the dimension of the network determines its gravitational pull, bigger networks are likely to keep their members for a longer time. Relationships nurtured through such networks are thus less likely to cool over time, and the depreciation rate γ probably exhibits a lower value. Everyday Facebook experience indeed suggests that users who temporarily move away from the platform are very likely to come back. Upon their return, they will find the network as they left it, making it easy to engage in the same old relationships again. Another technological factor that may decisively affect the social capital of the Web is the diffusion of broadband. Online networks can attract new users only as far as people can be easily connected to the Web. The lack of proper infrastructure can thus be viewed as a factor reducing both the payoff of *SN* players and the elasticity β.

6 Welfare analysis

Let us now consider the welfare properties of the two attracting stationary states $(K_N, x) = (0,0)$ and $(K_N, x) = (\frac{\beta}{\gamma}, 1)$. Figure 3 shows the payoff $\Pi^{FF}(x, p)$ and the payoff $\Pi^{SN}(K_N, x, p)$ evaluated at $K_N = \frac{\beta}{\gamma}$, $\Pi^{SN}(\frac{\beta}{\gamma}, x, p)$. Notice that two cases are possible: $(0,0)$ may Pareto dominate $(\frac{\beta}{\gamma}, 1)$ (Fig. 3a) or vice-versa (Fig. 3b). In particular, $(0,0)$ Pareto dominates $(\frac{\beta}{\gamma}, 1)$ if $\Pi^{SN}(\frac{\beta}{\gamma}, 1, p) < \Pi^{FF}(0, p)$ while the opposite holds if $\Pi^{SN}(\frac{\beta}{\gamma}, 1, p) > \Pi^{FF}(0, p)$. Both these scenarios are consistent with conditions (4)-(5). As expected, our model does not provide clear-cut welfare implications, both $(\frac{\beta}{\gamma}, 1)$ and $(0,0)$ can be socially suboptimal destinations for the economy, depending on the payoff structure; therefore, both $(\frac{\beta}{\gamma}, 1)$ and $(0,0)$ can become "social poverty traps".

[9] See the list of major social networking sites provided by Wikipedia for a quick glance at the phenomenon: http://en.wikipedia.org/wiki/List_of_social_networking_websites

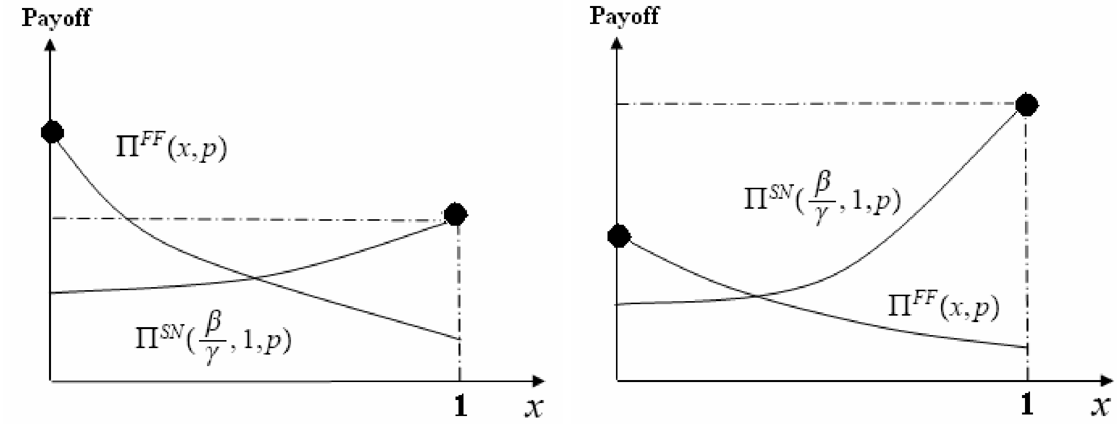

Figure 3: (a) Stationary state (0,0) Pareto dominates $\left(\frac{\beta}{\gamma},1\right)$; (b) Stationary state $\left(\frac{\beta}{\gamma},1\right)$ Pareto dominates (0,0).

7 Concluding remarks

This paper develops an evolutionary framework to explore the dynamics of social interaction in an environment where social relationships can be developed in two possible ways: through face to face encounters (the *FF* strategy), or by means of a mix of actual meetings and online interactions (*SN* strategy). Our findings suggest that the new opportunities for participation offered by social networking may progressively lead a growing share x of the population to embrace the *SN* strategy. The process is path dependent: the increase in x in fact rises the wealth of ties of the internet, thereby fostering the accumulation of online social capital and making social networking more and more attractive. At the end of the process, the economy is likely to converge to a state where all agents take care of their relationships both through face to face encounters and online networking, thereby expanding the stock of the internet's social capital at its highest possible level $\frac{\beta}{\gamma}$. In principle, the analysis cannot provide a precise evaluation of the social desirability of this scenario. Both the steady states $(\frac{\beta}{\gamma},1)$ and $(0,0)$ can in fact be socially suboptimal solutions to the model, depending on the payoff structure. In previous papers, we showed how the reduction in the time *p* devoted to social participation can trigger self-feeding processes leading to the progressive erosion of the stock of social capital. A decline in social participation may in fact reduce the productivity of the time spent on human interactions, thereby stimulating a process of substitution of relational goods with material ones, which in turn will cause a further decline in social participation (Antoci, Sabatini and Sodini 2010a, 2010b). The model in this paper completes our previous analyses by showing that, under certain conditions, the self-feeding process causing the erosion of the stock of social capital can be impeded by the new forms of web-mediated communication.

In previous works we analyzed a scenario in which time for social participation is an endogenous variable (i.e. it depends on agents' allocation choices) and social relationships can be developed just by means of face to face interaction (Antoci, Sabatini and Sodini 2010a, 2010b). In this paper, we address a scenario in which agents can interact with each other both through actual encounters and online networking, but *p* is exogeneously given.

The next step in our research programme will be the analysis of the agents' choice between the two possible strategies of social interaction within a new framework where the time *p* for social participation is not exogenously given anymore.

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