The Solaria Syndrome: Social Capital in a Growing Hyper-technological Economy

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28 February 2010

The Solaria Syndrome: Social Capital in a Growing Hyper-technological Economy

Paper presented at the Conference "From GDP to Well-Being: Economics on the Road to Sustainability", Ancona, Italy, 3-5 December 2009.

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February 28, 2010

Abstract

We develop a dynamic model to analyze the sources and the evolution of social participation and social capital in a growing economy characterized by exogenous technical progress. Starting from the assumption that the well-being of agents basically depends on material and relational goods, we show that the best-case scenarios hold when technology and social capital both support just one of the two productions at the expenses of the other. However, trajectories are possible where technology and social interaction balance one another in fostering the growth of both the social and the private sector of the economy. Along such tracks, technology may play a crucial role in supporting a "socially sustainable" economic growth.

Keywords: technology, economic growth, relational goods, social participation, social capital
JEL Codes: O33, J22, O41, Z13

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1 Introduction

Solaria was a planet inhabited by Spacer descendants[1]. The 50th and last Spacer world settled, it had perhaps the most eccentric culture of all of them. Originally, there were about 20,000 people living alone in vast estates. Solarians' lives were marked by technology: citizens never had to meet, save for sexual contact for reproductive purposes. All other contact was accomplished by sophisticated holographic viewing systems, with most Solarians exhibiting a strong phobia towards actual contact, or even being in the same room as another human. All work was done by robots: there were indeed thousands of robots for every Solarian. As centuries went by, Solaria became even more rigidly and obsessively isolationist. The planet cut off all contact with the rest of the Galaxy (although continuing to monitor hyperspatial communications). Its inhabitants genetically altered themselves to be hermaphroditic. At the final stage of Solarian civilization, the human inhabitants vanished, giving the impression that they had died out, although they had in fact withdrawn underground; their estates continued to be worked by millions of robots.

Solaria is a fictional planet in Isaac Asimov's Foundation and Robot series. The author draws on this metaphor to warn against the risks of dehumanization that may be brought about by an excessive and indiscriminate technical progress. In the 1950s, Asimov's novel well embodied the common fear according to which technology would have progressively destroyed social interaction. Today, at the beginning of the twenty-first century, our lives are marked by technology almost as those of Solarians. The widespread diffusion of the broadband, the internet revolution, and the true explosion of online networks like Facebook, Flickr and Twitter is worrying social scientists, who fear the risk of growing relational poverty. However, the evidence on such fears is not convincing. Drawing on GSS data, McPherson and Smith-Lovin (2006) show that social isolation mostly affects families with a high propensity to technological consumption. According to some authors, communication technologies lower the probability of having face-to-face visits with family, neighbors, or friends in one's home (Boase et al. 2006, Gershuny 2003, Nie et al., 2002). Wellman et al. (2006) note that internet usage may even interfere with communication in the home, creating a "post-familial family" where family members spend time interacting with computers, rather than with each other. Burke et al. (2009) find that more intensive Facebook use is associated with lower actual contact and higher loneliness. On the other side, Frenzen (2003) finds that internet use is not associated with a reduction in social interaction. Rather, the time devoted to the web is taken away from that spent on watching television. Drawing on survey data from a Canadian suburb, Hampton and Wellman (2003) show that

[1] The planet Solaria first appeared in "The naked sun", the second novel in Isaac Asimov's Robot series. The novel was first published in 1957 after being serialized in Astounding Science Fiction between October and December 1956. Solaria is also the background of the third novel of the Robot Series, "The robots of dawn", first published in 1983. Then, the planet appeared again in the fifth novel of the hyper-celebrated Foundation Series, "Foundation and Earth", first published in 1986.

high-speed access to the Internet enhances neighboring and increases contact with weaker ties. Ellison et al. (2007) find a positive and strong relationship between Facebook usage and bridging social capital in a sample of undergraduate students. More recent studies show that participation in online communities significantly enhances social capital in the form of networks and trust (Putnam and Kolko, 2009, Valenzuela et al., 2009, Vergeer and Pelzer, 2009a, 2009b). GSS data are used also by Robinson and Martin (2010), who find that internet use is not consistently correlated with lower levels of socializing or other social activities. This literature suffers from three main shortcomings: 1) results are conflicting; 2) the boom in online networks is so recent that we still lack suitable data to analyze the relationship between social participation and technology in the long run; the literature, still confined to the fields of applied psychology and computer-mediated communication, is mostly based on very limited case studies, so that its results can be hardly generalized; 3) in economics, we lack theoretical analyses addressing the causal mechanism. The relationship between growth, technology and social interaction has in fact been addressed mainly with regard to the ability of social norms and networks to foster economic growth (Knack and Keefer, 1997, Bartolini and Bonatti, 2002, Annen, 2003, Cozzi and Galli, 2009, Dearmon and Grier, 2009), or technology adoption both in developed high income areas (Burt, 1987, Akcomakak and ter Weel, 2009, Braguinsky and Rose, 2009), and in rural poor contexts (Conley and Udry, 2001, Barr, 2002, Isham, 2002). The reverse effects exerted by growth and technology on social participation are so far a rather neglected topic. Thus, it is still unpredictable whether the "Solaria syndrome" is an actual risk for developed countries. This paper aims to improve our understanding through a theoretical analysis addressing the sources and the evolution of social participation and social capital in a growing economy characterized by exogenous technical progress. We start from the assumption that the well-being of agents depends on the consumption of two goods: a private good and a socially provided one. Individuals allocate their time between "private" activities, i.e. the production and consumption of material goods, and social participation, i.e. the production and consumption of relational goods. Following Coleman (1988, 1990), we assume that social participation incidentally generates durable ties as a by-product. In the long run, such ties accumulate in a stock which constitutes the "social capital" of the economy. To implement the claims from the empirical literature (see Sabatini, 2007, for a review), we assume that such stock, besides facilitating social participation, also plays a role in the production of material goods. In principle, private and relational goods serve different needs. However, we introduce the possibility that, thanks to the help of technology, private goods can substitute for relational ones in the satisfaction of social needs. If the surrounding environment is socially poor, people may prefer to chat with unknown and distant people through the web instead of talking with neighbours. Even when material consumption is patently unable to satisfy social needs, it can at least compensate for the deprivation of human relations: for example, agents may comfort themselves for the lack of a bowling team by playing a virtual match against a computer. Following interesting hints from political science, we also assume that on the job interaction contributes to the creation of durable ties thereby influencing the time evolution of social capital (Karasek, 1976, Greenberg, 1986, Mutz and Mondak, 2006, Adman, 2008). In such a theoretical framework, we introduce an exogenous technical progress affecting the productivity of both the private and the relational spheres of the economy. This set of assumptions allows us to explain the growing social isolation often accompanying economic development as a result of the process of substitution between the two kinds of goods. Such process may cause the erosion of the entire stock of social capital, thereby leading the economy to fall down in a "social poverty" trap. Our primary research questions are: is it possible to avoid such collapse? Are there paths of sustainable development where technical progress and growth do not take place at the expenses of social participation? Or are we destined to live ever more comfortable, but isolated and unhappy, lives? Our work contributes to the literature by assessing whether the Solaria syndrome is an actual risk, in the belief that a better understanding of the mechanisms supporting the syndrome would be a first step along the path to find a cure. Namely, we identify a configuration of parameters under which the economy is more likely to reconcile growth and technology with social participation. Such a setting of the model offers guidelines for policy makers interested in improving the well-being of citizens through the preservation of the relational sphere of their lives. Moreover, we contribute to the cross-disciplinary debate by implementing into an analytical framework a complex set of assumptions modelled around the findings of the previous empirical literature in economics, sociology, and political science. The rest of the paper is organized as follows. The related literature and our main assumptions will be discussed in the review in Section 2 and within the set up of the model described in Section 3. Sections from 4 to 6 analyze the dynamics of the model. Section 7 addresses the effect of technical progress. The paper is closed by some concluding remarks.

2 Related literature

Human relations matter for happiness and well-being. This statement sounds so obvious that most people would be surprised to know that the analysis of social interactions is quite a novelty in the contemporary economic debate. In traditional economics, the agents' utility basically depends on material consumption and leisure time. In this framework, the economic action can be represented as a time allocation choice between working and leisure activities. Working allows people to gain the income necessary to buy those material goods that will be consumed in the leisure time. Such a narrow view of economics began to be questioned in the 1970s. According to Manski (2000), "Since then a new phase has been underway, in which the discipline seeks to broaden its scope while maintaining the rigor that has become emblematic of economic analysis" (115). As a result, the idea that the economic behavior of agents is deeply rooted in the social and moral spheres of their lives is now commonly accepted in the debate. Still, it is worth noting that this view is notably older than either the recent behavioral economics literature or the modern economic sociology. Explanations of the embeddedness of the economic action can in fact be easily retrieved in the work of the classical economists. While it is generally acknowledged that, in the work of Marx and Ricardo, economic actors are deeply socialized, a number of authors find traces of the typical codewords pervading the social capital literature (e.g. trust, norms, values, altruism, sympathy, and so on) in the work of Smith as well (see for example Becker, 1981, Bruni, 2000, Fontaine, 2000). In the Lectures on Jurisprudence, Smith states: "A dealer is afraid of losing his character, and is scrupulous in performing every engagement. When a person makes perhaps 20 contracts in a day, he cannot gain so much by endeavouring to impose on his neighbours, as the very appearance of a cheat would make him lose. Where people seldom deal with one another, we find that they are somewhat disposed to cheat, because they can gain more by a smart trick than they can lose by the injury which it does their character. (1763/1978, 539). Smith's argument basically refers to trading relationships, but it can be easily generalized to every kind of interaction. A social environment rich of participation opportunities, which allow people to meet frequently, creates a fertile ground for nurturing trust and shared values. The higher likelihood of repeated interactions increases the opportunity cost of free-riding in prisoner's dilemma kind of situations, thereby making the agents behaviour more foreseeable and causing an overall reduction of uncertainty. In other words, social interactions are a vehicle for the diffusion of information and trust which inevitably affect the economic activity, so that the two spheres of individual action continuously fade one another. Such claims more or less explicitly ground most of the contemporary social capital research in economics. Smith's view is similar to the modern theories of social capital developed in sociology by Granovetter (1973), who argues that social ties work as bridges through which information and trust spread across diverse communities and socioeconomic backgrounds. On the other side, the value of reputation and social approval is considered by Smith one of the main engines of human action. The importance of social approval is further stressed by Bentham (1789), who makes a step forward by mentioning 15 basic wants grounding the economic action. Among them, the author lists the pleasures of being on good terms with others, the pleasures of a good name, the pleasures resulting from the view of any pleasure supposed to be possessed by the beings who may be the objects of benevolence, and the pleasures resulting from the view of any pain supposed to be suffered by the beings who may become the objects of malevolence. The agents described by classical economists are thus deeply rooted in the social context, and their economic activities strictly depend on the complex of norms and relationships surrounding them. In our framework, the embeddedness of economic action takes the form of a continuous osmosis between the private and the relational spheres of the agents' lives. As it will be better outlined in the next section (devoted to the set up of the model), such osmosis is modelled through the assumption that the well-being of the representative agent depends on the consumption of two types of good: material goods, which in principle are produced in the private sphere of individuals, and socially provided goods, concerning the relational life of agents. Relational goods are a distinctive type of good that can only be enjoyed if shared with others. They are different from private goods, which are enjoyed alone, and standard public goods, which can be enjoyed by any number (Uhlaner, 1989). A peculiarity of relational goods is that it is virtually impossible to separate their production from consumption, since they coincide (Gui and Sugden, 2005). For example, a football match with friends is enjoyed (consumed) in the very moment of its production (i.e. the 90' spent on the sport field). The production processes of the two types of good are not separated. Rather, they continuously fade one another. The production and consumption of relational goods create durable ties which accumulate in a stock defined as social capital. We implement the claims from the empirical literature by assuming that such stock plays a crucial role in the production of material goods. From this point of view, we embrace the approaches proposed by the sociological and political science literature, where social capital is treated as a collective resource or, in other terms, as a public good (Bourdieu, 1980, 1986, Coleman,1988, 1990, Putnam, et al. 1993). At the same time, private production contributes to the accumulation of social capital too, since on the job interactions stimulate the creation of durable ties among workers (see the next section for a more detailed explanation of this hypothesis). Such ties in turn facilitate the production of new relational goods as well. In our framework, the osmosis between the aspects of life is even more evident when it brings about "negative" effects, i.e. when the expansion of one of the spheres causes a shrinking of the other. For example, the model shows the conditions under which an increase in the importance of private production and consumption may lead to social isolation, moreover pointing out which role technology may play in such a substitution process.

3 Set up of the model

We consider a population of size 1 constituted by a continuum of identical agents. We assume that, in each instant of time t, the well-being of the representative agent depends on the consumption $C(t)$ of a private good and on the consumption $B(t)$ of a socially provided good. We assume that $B(t)$ is produced by means of the joint action of the time devoted by the representative agent to social activities, $s(t)$, of the economy-wide average social participation $\overline{s}(t)$ and of the stock of social capital $K_s(t)$:

$$B(t) = F\left[s(t), \overline{s}(t), K_s(t)\right] \tag{1}$$

The average social participation $\overline{s}(t)$ and the current stock of social capital $K_s(t)$ are crucial arguments, since relational goods can only be enjoyed if shared with others (Uhlaner, 1989). If the social environment is rich of participation opportunities, because many people participate ($\overline{s}(t)$ is high) and there are well-established networks of relations ($K_s(t)$ is high), then the individual production of relational goods is easier (Antoci et al., 2005, 2007). Still, the production of relational goods requires a certain effort by individuals as well, $s(t)$. The time the representative agent does not spend on social participation, $1-s(t)$, is used as an input in the production of the output $Y(t)$ of the private sector.

Starting from the assumption that social capital can be treated as a factor of production or, at least, as a factor affecting transaction costs (see for example Paldam and Svendsen, 2000), we model one of the most debated claims from the empirical literature by assuming that social capital also plays a role in the production process of the private good.

In addition, for simplicity, we assume that $C(t) = Y(t)$, that is $Y(t)$ cannot be accumulated, and that the production process of $Y(t)$ requires only the inputs $1 - s(t)$ and $K_s(t)$:

$$C(t) = Y(t) = G\left[1 - s(t), K_s(t)\right] \tag{2}$$

The functions F and G in (1) and (2) are assumed to be strictly increasing in each argument. Note that $1 - s(t)$ can be interpreted as the time spent both *to produce* and *to consume* $C(t)$.

For simplicity, we consider the following Cobb-Douglas specifications for (1),(2):

$$Y(t) = [1 - s(t)] \cdot K_s^{\alpha}(t) \tag{3}$$

$$B(t) = s^{\beta}(t) \cdot \overline{s}^{1-\beta}(t) \cdot K_s^{\gamma}(t) \tag{4a}$$

Where $\alpha, \gamma > 0$ and $1 > \beta > 0$; the parameters β, $1-\beta$ and γ are the elasticities of B with respect to s, $\overline{s}$ and K_s, respectively:

$$\frac{\frac{\partial B}{\partial s}}{B} s = \beta, \qquad \frac{\frac{\partial B}{\partial \overline{s}}}{B} \overline{s} = 1 - \beta, \qquad \frac{\frac{\partial B}{\partial K_s}}{B} K_s = \gamma$$

In particular, β represents the agents' ability to contribute to the production/consumption of relational goods through their own effort into social participation, given the participation of the others and the stock of social capital. Such parameter may depend on a series of "psychological", "cultural", and "technological" factors. From a psychological point of view, it is noteworthy that charismatic agents may be able to carry away other people in interpersonal relations even if the surrounding environment is not rich of social participation opportunities, i.e. if $\overline{s}(t)$ and $K_s(t)$ are low, or if $1 - \beta$ and γ are low. Sociological studies have indeed claimed that charismatic agents behaving as leaders in networks may act as catalysts for the creation of social capital (see for example Burt, 1999).

The time evolution of social capital is assumed to depend on the average social participation $\overline{s}$, on the aggregate time spent on the production and consumption of the private good $1 - \overline{s}$ and on the stock of social capital:

$$\dot{K}_s = I(\overline{s}, 1 - \overline{s}, K_s) - \eta K_s = \overline{s}^{\delta} \cdot (1 - \overline{s})^{\varepsilon} \cdot K_s - \eta K_s \tag{5}$$

where $\dot{K}_s(t)$ indicates the time derivative of $K_s(t)$, and $1 > \delta, \varepsilon, \eta > 0$. The exponent of K_s in the function $I(\overline{s}, 1-\overline{s}, K_s)$ is assumed to be equal to 1 since we aim at analyzing a context in which the unbounded growth of K_s is (at least a priori) possible; however, posing the exponent strictly higher than 1 gives rise to "explosive" growth paths of K_s along which K_s goes to infinity in finite time. The parameter η indicates the depreciation rate of K_s; its value is positive because social ties need care to be preserved over time.

The parameters δ and ε measure the elasticities, with respect to the variables $\overline{s}$ and $1-\overline{s}$, of the "investment function" I in social capital:

$$\frac{\frac{\partial I}{\partial \overline{s}}}{I}\overline{s} = \delta, \qquad \frac{\frac{\partial I}{\partial (1-\overline{s})}}{I}(1-\overline{s}) = \varepsilon$$

If $\varepsilon = 0$, then the production of the private good has no effect on the time evolution of social capital. If $\delta = 0$, the accumulation of social capital is not influenced by social participation.

In our framework, social participation takes the form of the consumption of relational goods. Following Coleman (1988), we assume that the networks of durable ties forming the stock of social capital are created and strengthened as an incidental by-product of social participation, to an extent determined by the elasticity δ. However, we assume that durable ties may flourish in the context of private production as well, to an extent measured by the elasticity ε. Friendships often start on the workplace. It is noteworthy that, in political science, several schools of thought claim that citizens can develop their relational and political attitudes on the job (Mutz and Mondak, 2006). Moreover, the workplace is a training ground where people improve those communication and organizational abilities which are crucial for the production and consumption of relational goods (Karasek, 1976). Last but not least, besides its productive purposes, the workplace can be seen as a "social structure". Being involved in such structure helps agents to nurture their self-esteem, thereby raising their will and ability to engage in interpersonal relationships. By contrast, the condition of being outside the structure hampers social interaction through at least two channels, related to: a) the lack of the material resources that are often complementary for the production/consumption of relational goods (e.g. the money for paying the sports equipment); b) the fall in life-satisfaction, which can lead to forms of depression encouraging social isolation (Clark and Oswald, 1994, Benz and Frey, 2008, Brereton et al., 2008, Corneließen, 2009, Knabe and Rätzel, 2009).

The model also acknowledges the path-dependent nature of social capital. According to prominent authors emphasizing the "cultural" nature of social capital (see for example Fukuyama, 1995, and the conclusions of the "Italian work" by Putnam et al., 1993), norms and networks are deeply rooted in the past history of a territory. In this paper, the time evolution of social capital depends also on the current level of its stock. Note that arguments $\overline{s}$, $1-\overline{s}$, and K_s are all essential for the creation of social capital. If just one among $\overline{s}$, $1-\overline{s}$, and K_s is equal to zero, then the time evolution of social capital will be negative, due to the depreciation phenomenon.

Finally, we assume that the instantaneous utility of the representative agent is represented by the following *CES* function:

$$U(C,B) = [\lambda C^{-\theta} + (1-\lambda)B^{-\theta}]^{-\frac{1}{\theta}} \tag{6}$$

where $\theta \in (-1, +\infty)$, $\theta \neq 0$, and $\lambda \in (0,1)$. Here we model the assumption that the agents' well-being depends on private and relational goods. As we state in the introduction, these goods serve different needs. However, we introduce the possibility that private goods substitute for relational ones in the satisfaction of social needs, or, at least, for compensating the deprivation of human interactions. For example, a material, highly technological intensive, good like a playstation can (partially) console for the unavailability of 21 friends to play football on a sport field. The extent to which such substitution processes can take place is given by the parameter λ, which represents the relative weight of private consumption in the agents' utility function, and by $\rho = \frac{1}{1+\theta}$, measuring the (constant) elasticity of substitution between C and B.

For $\theta \to 0$, we have $\rho \to 1$, so (6) approaches the Cobb-Douglas utility function; for $\theta > 0$ (respectively, $\theta < 0$), the elasticity of substitution between C and B is lower (higher) than that of the Cobb-Douglas utility function. We will refer to the case $\theta > 0$ (respectively, $\theta < 0$) by saying that there is "low" (respectively, "high") substitutability between B and C or that B and C are "complements" (respectively, "substitutes").

For $\theta \to -1$, the goods C and B tend to be *perfect substitutes*, that is $\rho \to +\infty$. If this condition holds, then the utility of a combination of C and B is an increasing function of the sum of the two amounts. If there is a price difference, there would be no demand for the more expensive good. The substitution of material goods for relational activities sounds likely, if not unavoidable, and it is immediately evident that technology may play a fundamental role in such a process.

For $\theta \to +\infty$, $\rho \to 0$: in this case, the goods C and B tend to be *perfect complements*. In this extreme case, material and relational goods are like the right and the left piece of a pair of shoes and the representative agent has a Leontief-like utility function, such that $U(C,B) = \min\{C, B\}$. In this context, even the most sophisticated playstation will not compensate for the lack of a "team" of friends to play and interact with.

We assume that the representative agent solves the following maximization problem:

$$\max_{s(t)} \int_0^{+\infty} U(C,B)e^{-rt}dt \tag{7}$$

under the constraint (5); the parameter r measures the subjective discount rate. Being economic agents a continuum, the choice of $s(t)$ by each agent has no effect on the aggregate value $\overline{s}(t)$; consequently, in each instant of time t, the representative agent takes $\overline{s}(t)$ and $K_s(t)$ as exogenously given. This implies that, for every instant of time t, the solution $s(t)$ of problem (8) coincides with the solution of the following static maximization problem:

$$\max_s \left\{ \left[(1-s)\cdot K_s^{\alpha}\right]^{-\theta} + \left(s^{\beta}\cdot \overline{s}^{1-\beta}\cdot K_s^{\gamma}\right)^{-\theta} \right\}^{-\frac{1}{\theta}} \tag{8}$$

subject to the constraint $s \in [0,1]$.

4 The evolution of social participation

Since all agents make the same choice of $s(t)$, the aggregate social participation $\overline{s}(t)$ coincides (ex post) with the social participation $s(t)$ chosen by the representative agent. Writing the first order conditions for problem (8) (given $\overline{s}(t)$) and substituting (ex post) $\overline{s}(t) = s(t)$, we obtain the Nash equilibrium value $s^*(t)$ of $s(t)$, for each instant of time t:

$$s^* = \frac{\left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}}{\left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} + 1} \tag{9}$$

where $1 > s^* > 0$ always holds.
Note that s^* is increasing in β, i.e. social participation increases with the ability of agents to influence their relational sphere through their own effort (see (4a)).
The following proposition shows how the equilibrium social participation s^* varies according to an increase in the stock K_s of social capital.

Proposition 1 *The Nash equilibrium value s^* of social participation is increasing in K_s if $\theta(\alpha-\gamma) > 0$ and decreasing if $\theta(\alpha-\gamma) < 0$.*

The proof of this proposition is straightforward. Note that α and γ are the elasticities with respect to K_s of the private production Y and of the production/consumption of the relational good B, respectively:

$$\frac{\frac{\partial Y}{\partial K_s}}{Y}K_s = \alpha, \qquad \frac{\frac{\partial B}{\partial K_s}}{B}K_s = \gamma$$

Remember that, for $\theta > 0$, the elasticity of substitution between C and B is lower than that of the Cobb-Douglas utility function.
Summarizing, the time allocation choice s^* is determined by the degree of substitutability between C and B and by the relative importance of social capital K_s in the production of the two types of good (expressed by the sign of the difference $\alpha-\gamma$). In particular, we have that:

1. If $\theta > 0$, i.e. there is "low" substitutability between C and B (C and B are "complements") and if the "importance" of K_s in the production of Y is higher than in the production/consumption of B (that is, if $\alpha > \gamma$), then the equilibrium social participation s^* is increasing in K_s. In this context, agents will be interested in preserving the production of the good where productivity has registered the lower increase[2]. Under this parameters'

[2] Remember that, if $\theta \to +\infty$, then the utility function "converges" to a Leontief-like form.

configuration ($\theta > 0$ and $\alpha > \gamma$), after an increase in K_s, the productivity of time grows less in the "social" than in the "private" sphere. Then, agents will devote more time to relational activities. They will not be willing to "commodify" all their time, and social participation is more likely to be preserved.

A positive correlation between s^* and K_s also exists if $\theta < 0$, i.e. there is "high" substitutability between C and B (C and B are "substitutes"), and $\alpha < \gamma$ (K_s is less important in the production of Y than in the production/consumption of B). In this case, after an increase in social capital, agents will devote more time to social participation because the "social" sector has higher returns. Thanks to the high degree of substitutability, individuals will be willing to replace private goods with relational ones.

2. In the same way, a negative correlation between s^* and K_s exists if $\theta > 0$ and $\alpha < \gamma$ or if $\theta < 0$ and $\alpha > \gamma$.

   In fact, if there is low substitutability between C and B ($\theta > 0$) and K_s is more important in the production/consumption of B than in the production of C ($\alpha < \gamma$), then agents will be interested in preserving private production at the expenses of social participation. If there is high substitutability ($\theta < 0$) and K_s is more important in the production of C than in that of B ($\alpha > \gamma$), then agents will devote more time to the sector with higher returns. Thus, they will replace relational goods with private ones, once again at the expenses of social participation.

The results described above can be summarized as follows. If the two goods are "complements", individuals will devote more time to the production with lower returns. In this case, if an increase in the stock of social capital makes the productivity in the private sector grow less than that in the relational sector, then agents will reduce their social participation, in order to obtain a balanced growth of their material and relational consumptions. Think for example to a narrow-minded social environment where going out with friends requires expensive clothes and a prestigious car. Here, a strengthening of the existing networks will lead agents to work more, at the expenses of social participation, in order to earn the income necessary for acquiring material goods. If the substitutability between the two goods is "high", then the representative agent will devote more time to the sector with higher returns.

Clearly, the degree of substitutability between private and relational goods plays a key role in the evolution of social participation. The parameter θ may be shaped mainly by moral and cultural factors. For example, a culture exalting the prominence of reciprocity and solidarity in social life, and acknowledging the importance of non market relations in respect to material consumption, may noticeably reduce the elasticity of substitution between C and B. If people are not willing to "commodify" all their time, then the replacement of relational goods with material ones may be perceived as too painful. In such a scenario, social participation is more likely to be preserved. In a more materialistic society, where material possessions are believed to fill all human needs and are perceived as a distinctive feature of the quality of life, the degree of substitutability is likely to be higher. Moreover, in this cultural context, agents may be more tempted to exploit human relations to the purposes of increasing their material wealth. An additional result is that any possible increase in the stock of social capital is likely to raise the productivity in the private sector more than in the social sphere of life. In our framework, such a scenario leads to a parameters' configuration ($\theta < 0$ and $\alpha > \gamma$) which creates the premises for a progressive reduction in social participation over time.

5 Dynamics

In equation (5), $\overline{s}(t)$ must be replaced by the solution s^* to the problem (8). The resulting dynamics are not optimal. However, each trajectory under such dynamics represents a Nash equilibrium path of the economy in that, along it, no agent has an incentive to modify his choices if the others do not revise theirs as well.
The (Nash) equilibrium dynamics can be written as follows:

$$\begin{aligned}\dot{K}_s &= \left[\frac{\left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}}{\left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}+1}\right]^{\delta} \frac{K_s}{\left[\left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}+1\right]^{\varepsilon}} - \eta K_s = \\ &= \frac{h^{\delta} K_s^{\delta\theta\frac{\alpha-\gamma}{\theta+1}+1}}{\left(hK_s^{\theta\frac{\alpha-\gamma}{\theta+1}}+1\right)^{\varepsilon+\delta}} - \eta K_s \qquad (10)\end{aligned}$$

where $h := \left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} > 0$. The following propositions show the basic properties of dynamics (10). In the remaining part of the paper, propositions' proofs will be omitted when straightforward.

Proposition 2 *Along the trajectories of equation (10), the values of the utility function U and of K_s are positively correlated. This implies that if there exist two steady states $\overline{K}_s^1$ and $\overline{K}_s^2$ such that $\overline{K}_s^2 > \overline{K}_s^1$, then $\overline{K}_s^2$ Pareto-dominates $\overline{K}_s^1$; that is, $\overline{K}_s^1$ is a poverty trap, when attracting.*

Proposition 3 *If $\alpha \neq \gamma$, a perpetual growth path of the stock of social capital K_s does not exist under equation (10); that is, no trajectory exists along which $K_s \to +\infty$ for $t \to +\infty$.*

Proof. Suppose that such perpetual growth path exists. Then there exists $\widehat{t}$ such that $\frac{\dot{K}_s}{K_s} = K_s^{\delta\theta\frac{\alpha-\gamma}{\theta+1}} \frac{h^{\delta}}{\left(hK_s^{\theta\frac{\alpha-\gamma}{\theta+1}}+1\right)^{\varepsilon+\delta}} - \eta > 0$, $\forall t > \widehat{t}$. But under such hypothesis, we have $\lim_{t \to +\infty} K_s^{\delta\theta\frac{\alpha-\gamma}{\theta+1}} \frac{h^{\delta}}{\left(hK_s^{\theta\frac{\alpha-\gamma}{\theta+1}}+1\right)^{\varepsilon+\delta}} = 0$. Then there exists t' such that $\frac{\dot{K}_s}{K_s} < 0$, $\forall t > t'$, which is a contradiction. ■

In the context $\alpha \neq \gamma$, an increase in K_s generates an increase in s^* (i.e. in $\overline{s}$) and consequently a reduction in $1 - s^*$, or vice-versa; in both the cases, the coefficient $\overline{s}^{\delta}(1-\overline{s})^{\varepsilon}$ of K_s in equation (5) approaches 0 for high enough values of K_s, thereby hampering the accumulation of social capital over time. This motivates the nonexistence of trajectories along which K_s grows without bound. Only in the context $\alpha = \gamma$, in which an increase in K_s does not affect the time allocation between social and private activities, the economy can follow a trajectory of unbounded growth of K_s. In such a case, social participation s^* is not affected by variations in K_s and social capital grows at the rate:

$$\frac{\dot{K}_s}{K_s} = \frac{h^{\delta}}{(h+1)^{\varepsilon+\delta}} - \eta$$

which is strictly positive if $\eta < h^{\delta}/\left(h+1\right)^{\varepsilon+\delta}$. Such a condition is more likely to hold when the depreciation rate of social capital η, and the relative weight of private consumption λ have a low value. In other words, the unbounded growth of the stock of social capital is possible in a scenario where: a) agents are interested in taking care of their interpersonal relationships, thereby preventing their cooling over time; b) the consumption of material goods is of rather limited importance in determining life satisfaction.

Since an unbounded growth of K_s is not possible when $\alpha \neq \gamma$, every trajectory of equation (10) always approaches a stationary state.

The following proposition gives a complete classification of the possible dynamic regimes.

Proposition 4 *If $\alpha \neq \gamma$, the dynamic regimes under equation (10) can be classified as follows:*

(1) If $\eta < \left(\frac{\delta}{\varepsilon}\right)^{\delta}/(\frac{\delta}{\varepsilon}+1)^{\varepsilon+\delta}$, then three stationary states, $\overline{K}_s^0 = 0$, $\overline{K}_s^1$ and $\overline{K}_s^2$, with $\overline{K}_s^0 < \overline{K}_s^1 < \overline{K}_s^2$, exist. The stationary state $\overline{K}_s^1$ is repulsive while $\overline{K}_s^0$ and $\overline{K}_s^2$ are locally attractive (see Figure 1.a).

(2) If $\eta > \left(\frac{\delta}{\varepsilon}\right)^{\delta}/(\frac{\delta}{\varepsilon}+1)^{\varepsilon+\delta}$, then the stationary state $\overline{K}_s^0 = 0$ is globally attractive (see Figure 1.b).

Proof. $\overline{K}_s^0 = 0$ is always a stationary state. The other stationary states are given by the solutions of the equation:

$$g(K_s) := \frac{h^{\delta} K_s^{\delta\theta\frac{\alpha-\gamma}{\theta+1}}}{\left(hK_s^{\theta\frac{\alpha-\gamma}{\theta+1}}+1\right)^{\varepsilon+\delta}} = \eta$$

It is easy to check that $\underset{K_s\to 0}{lim} g(K_s) = \underset{K_s\to +\infty}{lim} g(K_s) = 0$ and that $g'(K_s) \gtreqless 0$ for $K_s \gtreqless K_s^* := \left(\frac{\delta}{h\varepsilon}\right)^{\frac{\theta+1}{\theta(\alpha-\gamma)}}$. Consequently, two stationary states exist if $g(K_s^*) > \eta$, that is, if $\eta < \left(\frac{\delta}{\varepsilon}\right)^{\delta} / \left(\frac{\delta}{\varepsilon}+1\right)^{\varepsilon+\delta}$. $\blacksquare$

According to the above proposition, the stationary state $\overline{K}_s^0 = 0$ is always locally attractive; such a poverty trap is avoidable (in the context (1) of the above proposition) starting from an initial value of K_s greater than $\overline{K}_s^1$. So $\overline{K}_s^1$ represents the threshold value separating the basins of attraction of $\overline{K}_s^0$ and $\overline{K}_s^2$. Once again, the depreciation rate of the stock of social capital plays a crucial role in determining the final destination of the economy. If it is low enough, then the economy may be attracted by the stationary state $\overline{K}_s^2$ characterized by positive endowments of social capital.

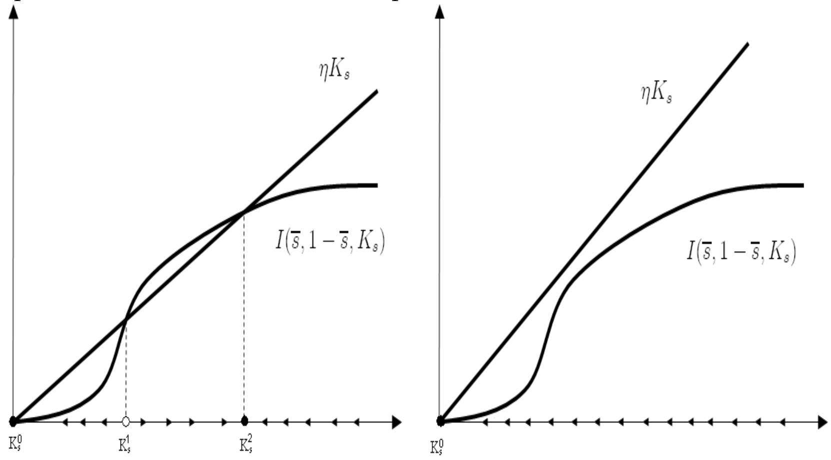

Figure 1: *(a) Dynamics in the context* $\eta < \left(\frac{\delta}{\varepsilon}\right)^{\delta} / \left(\frac{\delta}{\varepsilon}+1\right)^{\varepsilon+\delta}$ *(b) Dynamics in the context* $\eta > \left(\frac{\delta}{\varepsilon}\right)^{\delta} / \left(\frac{\delta}{\varepsilon}+1\right)^{\varepsilon+\delta}$

6 Social participation as the unique engine of the accumulation of social capital

The set up of the model described in the previous section accounts for the possibility that the time $1-\overline{s}$ spent in the production process of material goods plays a positive role in the accumulation of social capital,. As briefly outlined above, such a role basically unfolds through two main channels: a) the workplace constitutes a possibly fertile ground for nurturing interpersonal relationships and creating durable ties; b) the condition of being employed and integrated in a work structure fosters the workers' self-esteem, thereby improving his bent for social interaction. In our model's lexis, the above hypotheses are synthesized by a positive value of the parameter ε. In this section, we pose $\varepsilon = 0$ in order to analyze the dynamics under the assumption that social participation is the unique engine of the accumulation of social capital. By posing $\varepsilon = 0$ in (10) we obtain:

$$\dot{K}_s = \overline{s}^{\delta} K_s - \eta K_s = \left(\frac{h K_s^{\theta \frac{\alpha-\gamma}{\theta+1}}}{h K_s^{\theta \frac{\alpha-\gamma}{\theta+1}} + 1} \right)^{\delta} K_s - \eta K_s \tag{11}$$

The basic properties of dynamics under equation (11) are illustrated by the following proposition.

Proposition 5 *The stationary states of dynamics (11) are:*

$$\overline{K}_s^0 = 0, \qquad \overline{K}_s^1 = \left[\frac{\eta^{\frac{1}{\delta}}}{h\left(1 - \eta^{\frac{1}{\delta}}\right)} \right]^{\frac{\theta+1}{\theta(\alpha-\gamma)}}$$

(1) If $\theta(\alpha-\gamma) > 0$, then the stationary state $\overline{K}_s^0$ is locally attractive and $\overline{K}_s^1$ is repulsive (see Figure 2.a). The economy follows a growth trajectory along which $K_s \to +\infty$ if it starts from an initial value $K_s(0)$ greater than the threshold value $\overline{K}_s^1$.

(2) If $\theta(\alpha-\gamma) < 0$, then the stationary state $\overline{K}_s^0$ is repulsive and $\overline{K}_s^1$ is globally attractive (see Figure 2.b). The economy cannot follow a trajectory along which K_s grows without bound.

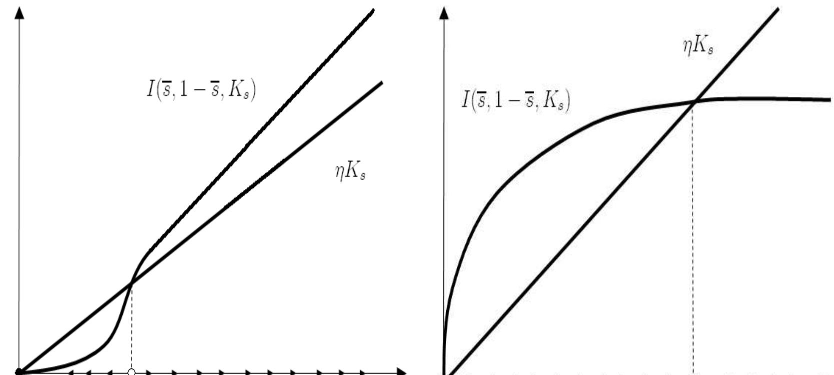

Figure 2: *(a) Dynamics in the context $\theta(\alpha-\gamma) > 0$ (b) Dynamics in the context $\theta(\alpha-\gamma) < 0$*

The proof of this Proposition is straightforward. According to it, the stock of social capital can follow a path of unbounded growth only if $\theta(\alpha-\gamma) > 0$, that is, in the context where the equilibrium social participation $s^*$is positively correlated to K_s. Such condition holds (see Proposition 1) if there is "low" substitutability between B and C (that is, if $\theta > 0$) and if the "importance" of

K_s in the production of C is higher than in the production/consumption of B (that is, if $\alpha > \gamma$) or in the opposite case $\theta < 0$, $\alpha < \gamma$.

In the case with low substitutability $\theta > 0$, $\alpha > \gamma$, agents will be interested in preserving the consumption of the good in whose production process productivity has registered the lower increase; so, after an increase in the stock of social capital, the productivity of the time spent on social participation grows less than that of the time spent on private activities. Agents will devote more time to the relational sphere of their lives. In the case $\theta < 0$, $\alpha < \gamma$, after an increase in social capital, agents will devote more time to social participation because the social sector has higher returns. In such a scenario, thanks to the high degree of substitutability, individuals will be willing to replace private goods with relational ones.

Being s^*positively correlated to K_s in the case $\theta(\alpha-\gamma) > 0$, the variations in the stock of K_s tend to be self-enforcing: an increase (respectively, a decrease) in K_s leads to an increase (decrease) in s^* which in turn gives rise to a further increase (decrease) in K_s. This mechanism explains the coexistence between growth paths approaching the poverty trap $\overline{K}_s^0 = 0$ and growth paths along which K_s grows without bound. The opposite holds in the context $\theta(\alpha - \gamma)$, where the negative correlation between s^* and K_s does not lead the economy neither to approach $\overline{K}_s^0 = 0$ nor to follow a path of perpetual growth of K_s.

7 Exogenous technological progress

In the framework developed in the previous sections, the degree of substitutability between private and relational goods plays a key role in the evolution of social participation. As we already hinted in the introduction, it is rather intuitive that technology can in turn crucially influence the substitution process. In this section, we introduce exogenous technical progress in the scenarios where an unbounded growth of the stock of social capital is possible. The primary research questions to which we aim to provide an answer here are: which is the role of technology in determining the trajectories of the economy in respect to social participation and social capital? Is the Solaria syndrome an actual risk? If this is the case, a better understanding of the mechanisms supporting the syndrome would be a first step along the path to find a cure.
Here we assume that technical progress raises the productivity both in the private and in the relational sectors. The assumption is based on the observation that technology can help the production of relational goods in a variety of ways. Communication technologies are of great support in establishing new ties with unknown people (this is often the case of online networks like Facebook and Flickr and, more in general, of the infrastructures allowing their diffusion, like computers and the broadband), in keeping in touch with old friends (think for example of Friendfeed and Twitter, or about the ability of Facebook to reconnect people with school and college mates), and in arranging meetings with kin and friends we are used to see in our everyday life (besides the online networks cited above, consider for example the unquestionable role of cell-phones, emails,

and newer tools like Skype and Messenger). The production functions of the two goods can now be expressed as:

$$
\begin{aligned}
Y(t) &= [1 - s(t)] \cdot K_s^{\alpha}(t) \cdot T^{\pi}(t) \\
B(t) &= s^{\beta}(t) \cdot \overline{s}^{1-\beta}(t) \cdot K_s^{\gamma}(t) \cdot T^{\psi}(t)
\end{aligned}
$$

where π, $\psi > 0$ are parameters and T represents technological progress, growing at the exogenous rate $\mu > 0$:

$$
\dot{T} = \mu T \tag{12}
$$

According to (12), $T(t) = T(0)e^{\mu t}$ holds.
In this context, the time allocation choice and the accumulation dynamics of social capital are given by:

$$
s^* = \frac{hT^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}}{hT^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} + 1} \tag{13}
$$

$$
\dot{K}_s = \left(\frac{hT^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}}{hT^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} + 1} \right)^{\delta} \cdot K_s - \eta K_s \tag{14}
$$

where $h := \left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} > 0$. In order to analyze (14), we define the variable:

$$
H := T^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} \tag{15}
$$

whose time derivative is given by:

$$
\begin{aligned}
\dot{H} &= \theta T^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} \left(\frac{\alpha-\gamma}{\theta+1}\frac{\dot{K}_s}{K_s} + \frac{\pi-\psi}{\theta+1}\frac{\dot{T}}{T} \right) = \\
&= \frac{\theta}{\theta+1} H \left[(\alpha-\gamma)\frac{\dot{K}_s}{K_s} + (\pi-\psi)\frac{\dot{T}}{T} \right] = \\
&= \frac{\theta}{\theta+1} H \left[(\alpha-\gamma) \left(\frac{hT^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}}}{hT^{\theta\frac{\pi-\psi}{\theta+1}} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} + 1} \right)^{\delta} + (\pi-\psi)\mu - (\alpha-\gamma)\eta \right] = \\
&= \frac{\theta}{\theta+1} H \left[(\alpha-\gamma) \left[\left(\frac{hH}{hH+1} \right)^{\delta} - \eta \right] + (\pi-\psi)\mu \right]
\end{aligned} \tag{16}
$$

Notice that (16) admits at most one stationary state with $H > 0$. Such stationary state exists if and only if:

$$
1 > \frac{\eta(\alpha-\gamma) - \mu(\pi-\psi)}{\alpha-\gamma} > 0 \tag{17}
$$

and it is given by:

$$H^* = \frac{1}{h} \frac{\left[\frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma}\right]^{\frac{1}{\delta}}}{1-\left[\frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma}\right]^{\frac{1}{\delta}}} \tag{18}$$

When $H \to +\infty$, the right side of (16) tends to:

$$\frac{\theta}{\theta+1} H \left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right]$$

i.e. dynamics (16), for H high enough, can be approximated by the following equation:

$$\dot{H} = \frac{\theta}{\theta+1} H \left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right]$$

Thus, in order to obtain $\dot{H} > 0$ in the lung run, the following condition must hold:

$$\frac{\theta}{\theta+1} \left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right] > 0 \tag{19}$$

Along the trajectories where $\dot{H}$ remains definitively positive, the time evolution of H is thus approximated by the following function:

$$H(t) = H(0) e^{\frac{\theta}{\theta+1}\left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right]t} \tag{20}$$

Since (16) is an autonomous differential equation, the analysis outlined above allows us to carry out a complete classification of the dynamic regimes under (16) based on the conditions (17) and (19).

Proposition 6 *The dynamic regimes generated by the equation (16) can be classified as follows:*

1. If $1 > \frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma} > 0$ *and* $\frac{\theta}{\theta+1}\left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right] > 0$*, then there exists an interior stationary state* H^**, which is repulsive. Starting from an initial value* $H(0) < H^*$*, then* $H \to 0$*; starting from* $H(0) > H^*$*, then* $H \to +\infty$*.*

2. If $1 > \frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma} > 0$ *and* $\frac{\theta}{\theta+1}\left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right] < 0$*, then there exists an interior stationary state* H^**, which is globally attractive.*

3. If $\frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma} < 0 \vee \frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma} > 1$ *and* $\frac{\theta}{\theta+1}\left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right] > 0$*, then an interior stationary state* H^* *does not exist and* $H \to +\infty$ *for every initial value* $H(0) > 0$*.*

4. If $\frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma} < 0 \vee \frac{\eta(\alpha-\gamma)-\mu(\pi-\psi)}{\alpha-\gamma} > 1$ *and* $\frac{\theta}{\theta+1}\left[(1-\eta)(\alpha-\gamma)+\mu(\pi-\psi)\right] < 0$*, then an interior stationary state* H^* *does not exist and* $H \to 0$ *for every initial value* $H(0) > 0$*.*

According to the above proposition, it is easy to check that the following three different scenarios can occur:

Scenario 1: $H = T^{\frac{\theta}{\theta+1}(\pi-\psi)} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} \to 0$ (cases 1 and 4 of the above proposition). In this case, $s^* \to 0$ and consequently $K_s \to 0$, for $t \to +\infty$.

Scenario 2: $H = T^{\frac{\theta}{\theta+1}(\pi-\psi)} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} \to +\infty$ (cases 1 and 3). In this case, $s^* \to 1$ and consequently $K_s \to +\infty$, for $t \to +\infty$.

Scenario 3: $H = T^{\frac{\theta}{\theta+1}(\pi-\psi)} K_s^{\theta\frac{\alpha-\gamma}{\theta+1}} \to H^*$ (case 2). In this case, K_s behaves differently according to the sign of θ, $\alpha - \gamma$ and $\pi - \psi$. In particular, if $\theta(\pi - \psi) > 0$, then $T^{(\pi-\psi)\frac{\theta}{\theta+1}} \to \infty$ holds and consequently $K_s \to 0$ or $K_s \to +\infty$ holds if, respectively, $\theta(\alpha - \gamma) > 0$ or $\theta(\alpha - \gamma) < 0$. If $\theta(\pi - \psi) < 0$, then $T^{(\pi-\psi)\frac{\theta}{\theta+1}} \to 0$ holds and consequently $K_s \to +\infty$ or $K_s \to 0$ holds if, respectively, $\theta(\alpha - \gamma) > 0$ or $\theta(\alpha - \gamma) < 0$.

When T equally contributes to the production of material and relational goods (i.e. $\pi = \psi$), the time allocation choices are not affected by technical progress. In this extreme case, we have the same results obtained in the framework without exogenous technical progress.

The above proposition shows that either $K_s \to 0$ or $K_s \to +\infty$ may hold, that is, K_s cannot approach a strictly positive value.

The previous proposition has the following corollary, which provides the necessary and sufficient conditions allowing for the existence of trajectories along which $K_s \to +\infty$:

Proposition 7 *Under dynamics (16), there exist trajectories along which* $K_s \to +\infty$ *if and only if either*[3]

a) $(\alpha - \gamma)(\pi - \psi) < 0$ *(that is,* $\alpha - \gamma$ *and* $\pi - \psi$ *have opposite signs) or*

b) $sign(\theta) = sign(\alpha - \gamma) = sign(\pi - \psi)$ *(that is,* $\alpha - \gamma$, $\pi - \psi$ *and* θ *have the same sign).*

It is worth noting that condition *b)* is analogous to that allowing for an unbounded growth of K_s in the model without technical progress, which can be rewritten as follows:

$$sign(\theta) = sign(\alpha - \gamma) \tag{21}$$

Thus, comments to Proposition 5 also apply to condition *b)*. The scenarios described by this condition are characterized by the fact that both technical progress and the accumulation of social capital cause a higher productivity increase in the same sector. If B and C are "complements" (i.e. $\theta > 0$), then the unbounded growth of social capital occurs if and only if an increase in T and K_s raises the productivity of the time spent on the production of private goods more than that of the time spent on social participation (case $\alpha - \gamma > 0$, $\pi - \psi > 0$). In such a context, agents are concerned with supporting the production process where productivity has registered the lower increase.

[3] For simplicity, we limit our analysis to "robust" cases, where $\alpha - \gamma \neq 0$ and $\pi - \psi \neq 0$.

Thus they will devote more time to relational activities, causing an increase in social participation which in turn fuels the accumulation process of K_s.

If B and C are "substitutes" ($\theta > 0$), then the satisfaction of condition *b)* requires that an increase in T and K_s improves the relative performance of the relational sector (case $\alpha - \gamma < 0$, $\pi - \psi < 0$). In such a case, after an increase in T and K_s, agents will devote more time to social participation because, thanks to the "high degree" of substitutability, they prefer to replace private goods with relational ones.

Condition *a)* of the above proposition deals with "mixed" contexts, where technical progress and social capital exert a diverse influence on the two sectors. Under such condition, there always exist trajectories along which $K_s \to +\infty$, whatever the sign of θ is. A typical mixed context occurs when technical progress raises the productivity in the private sector more than in the relational one ($\pi - \psi > 0$). In this case, K_s can tend to infinite only if increases in its stock play a higher role in the production of relational goods ($\alpha - \gamma < 0$). However, in previous sections we have acknowledged the possibility that increases in the stock of social capital raise the productivity in the private sector more than what they do in the social sphere of the individual action ($\alpha - \gamma > 0$). In the context of highly technology-intensive productions taking place in a mature economy, a good relational atmosphere inside the firm and in the surrounding social environment can in fact easily make the difference. In such a case, according to our results, the preservation of social participation is more likely if technical progress plays a higher role in the social sphere of individuals, rather than in the private production of material goods. This scenario is less weird than we could think at a first glance. Technology has literally invaded every sphere of our everyday life, included the field of social interactions. A growing part of our human interactions now takes place online, in the context of virtual networks like Facebook, Twitter, and Flickr, just to mention a few. For example, Meetic is an ever more popular place to arrange dates, and the number of engagements between people who met on Meetic-like platforms is exponentially growing in the last years. The context hypothesized by case *a)* of the previous proposition may thus look as a "socially sustainable" development path, along which technology and social interaction balance one another in fostering the growth of the private and the social sectors of the economy.

In other words, if certain conditions hold, and thanks to the boom in technology-driven communication and interaction, technical progress can push the economy to approach scenarios which are very far from the Solaria nightmare described in Asimov's novels. However, the possibility exists of a progressive reduction of the relational sphere of individuals, as it happens when conditions *a)* and *b)* of the above proposition are not satisfied. Asimov's Solaria is a world characterized by weak moral norms and the absence of any form of communitarian life, where material goods play an exaggerated role in determining life-satisfaction. A reader can enjoy himself in comparing his social environment (from the neighborhood to the nation-wide level) with Solaria, to imagine to what extent it is subject to contract the syndrome.

Figures 3.a and 3.b show, respectively, the time evolution of K_s and of well-being (measured by the value $U(C,B)$ of the utility function (6)) along the trajectory starting from the initial conditions $K_s(0) = 0.001$, $T(0) = 1$; parameter values are: $\alpha = 0.8$, $\beta = 0.1$, $\gamma = 0.12$, $\delta = 0.1$, $\eta = 0.61$, $\theta = 0.5$, $\lambda = 0.5$, $\mu = 0.13$, $\pi = 0.6$, $\psi = 0.1$. Note that the time evolution of K_s and $U(C,B)$ exhibits an initial growth followed by a decline.

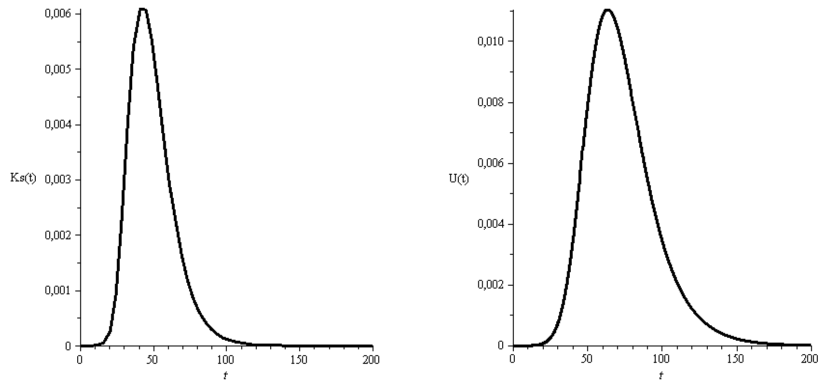

Figure 3: *(a) Time evolution of social capital (b) Time evolution of well-being*

Figure 4 shows an example of path dependence: the stock of social capital approaches zero along the trajectory starting from $K_s(0) = 600, T(0) = 0.1$ while it grows without bound along the that starting from $K_s(0) = 750, T(0) = 0.1$; parameter values are: $\alpha = 0.9$, $\beta = 0.81$, $\gamma = 0.29$, $\delta = 0.931$, $\eta = 0.9$, $\theta = 7.9195$, $\lambda = 0.2$, $\mu = 0.0053$, $\pi = 1$, $\psi = 0.2$.

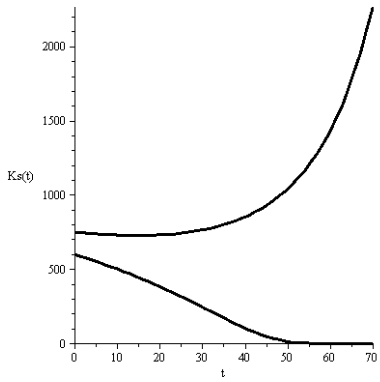

Figure 4: *An example of path dependence*

8 Concluding remarks

In our paper, we have analyzed the dynamics of an economy constituted by a continuum of identical agents whose well-being, measured by the *CES* function $U(C,B) = [\lambda C^{-\theta} + (1-\lambda)B^{-\theta}]^{-\frac{1}{\theta}}$, depends on the consumption of a private good C and on the consumption of a relational good B. The parameter θ measures the degree of substitutability between B and C, which are "complements" if $\theta > 0$ and "substitutes" if $\theta < 0$.

B and C are produced according to the production functions $B = s^{\beta} \cdot \overline{s}^{1-\beta} \cdot K_s^{\gamma}$ and $C = (1-s) \cdot K_s^{\alpha}(t)$, where s is the time devoted by the representative agent to social activities, $\overline{s}$ is the economy-wide average social participation and K_s is the stock of social capital. In this context, we have analyzed the interplay between consumption choices and social capital accumulation under the following alternative assumptions:

1. The time evolution of K_s is given by $\dot{K}_s = \overline{s}^{\delta} \cdot (1-\overline{s})^{\varepsilon} \cdot K_s - \eta K_s$, that is job interactions $(1-\overline{s})$ and social participation $(\overline{s})$ are both essential inputs of the accumulation process of social capital.

2. The time evolution of K_s is given by $\dot{K}_s = \overline{s}^{\delta} \cdot K_s - \eta K_s$, that is, social participation is the unique engine of the accumulation of social capital.

3. The time evolution of K_s is given by $\dot{K}_s = \overline{s}^{\delta} \cdot K_s - \eta K_s$ and, furthermore, is conditioned by exogenous technical progress T, which enters in the production functions of C and B: $C = (1-s) \cdot K_s^{\alpha} \cdot T^{\pi}$, $B = s^{\beta} \cdot \overline{s}^{1-\beta} \cdot K_s^{\gamma} \cdot T^{\psi}$.

We have shown that, under the assumption (1), no trajectory along which $K_s \to +\infty$ (for $t \to +\infty$) exists, in that either $\overline{s} \to 0$ or $\overline{s} \to 1$ (the limit of $\overline{s}$ depends on the sign of θ, i.e. on the degree of substitutability between C and B).

Under the assumption (2), trajectories along which $K_s \to +\infty$ exist if and only if the condition $\theta(\alpha-\gamma) > 0$ holds. That is, if there is "low" substitutability between B and C $(\theta > 0)$ and if the "importance" of K_s in the production of C is higher than in the production/consumption of B $(\alpha > \gamma)$, or in the opposite case $\theta < 0$, $\alpha < \gamma$. In both cases, the average social participation $\overline{s}$ is positively correlated with K_s. in fact, in the case $\theta > 0$, $\alpha > \gamma$ (C and B are "complements" and an increase in K_s increases the relative productivity of the time spent in the production of C), if K_s increases, agents raise their social participation to preserve the consumption of the good in whose production process productivity has registered the lower increase. On the other side, in the case $\theta < 0$, $\alpha < \gamma$, after an increase in social capital, agents will devote more time to social participation because the social sector has higher returns and B is a "substitute" for C.

Finally, under the assumption (3), trajectories along which $K_s \to +\infty$ exist if either *a)* $\alpha - \gamma$, $\pi - \psi$ and θ all have the same sign, or *b)* $\alpha - \gamma$ and $\pi - \psi$ have opposite signs. Condition *a)* describes scenarios where both technical progress and the accumulation of social capital cause a higher productivity increase in the same sector. Condition *b)* deals with "mixed" contexts, where technical progress and social capital exert a diverse influence on the two sectors. In this scenario, there always exist trajectories along which $K_s \to +\infty$, whatever the sign of θ is.

Even besides the inclusion of technical progress in the model, it is straightforward that technology plays a role in the substitution between material and relational goods, thereby crucially influencing the evolution of K_s. Intuition and literary fascinations may lead the reader to think that technology can possibly harm social interaction. However, if we introduce exogenous technical progress in the best-case scenarios (those where an unbounded growth of the stock of social capital is possible), we find that, in some cases, technology can work as an antidote to the destruction of human interaction feared in the Solaria metaphor. The possibly positive role of technology emerges clearly in "mixed" contexts, specially when increases in the stock of K_s support the private sector more than the relational one. In such a case, the existence of trajectories along which $K_s \to +\infty$ is always guaranteed as long as technical progress causes a higher productivity increase in the social sphere of the economy, whatever the sign of θ is. As outlined in the previous section, this scenario is less weird than we could think at a first glance. The marginal productivity of technology-driven communication can easily be higher in the production of relational goods, and Facebook and Twitter can be viewed as striking examples of this phenomenon. Configurations of the economy where social capital plays a major role in private activities, while technical progress crucially support human relationships, can thus be thinked of as socially sustainable development paths. Along such tracks, technology and social interaction can balance one another in fostering the growth of both the social and the private sector of the economy.

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