The Solaria syndrome: Social capital in a growing hyper-technological economy

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

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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, social networks
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civilization, the human inhabitants vanished, giving the impression that they had died out, although they had in fact withdrawn underground; their estates continued to be worked by millions of robots.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. 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, McPherson and Smith-Lovin, 2006, 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 high-speed access to the Internet enhances neighboring and increases contact with weaker ties. Ellison et al. (2007) find

[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.

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 one of the most popular claims emerging from the empirical literature, 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. 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 (Antoci et al. 2007, 2008). 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 4 and 5 analyze the dynamics of the model. Section 6 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 this stock may play 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). 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, 2008). 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 may play 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):

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

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

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

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

We assume that $\gamma > \alpha$ because even if we acknowledge that social capital may play a role in the production of material goods ($\alpha \geq 0$), it is likely for it to be more relevant in the production and consumption of relational goods. A positive average social participation $\overline{s}(t) > 0$ is always required for the production/consumption of $B(t)$, that is $B(t) = 0$ if $\overline{s}(t) = 0$ whatever the value of $K_s(t)$ is. If no one participates, single agents have no possibility to enjoy relational goods, even in presence of a positive stock of social capital. On the other hand, we account for the possibility that social capital may be an essential input in the production of material goods: in the context $\alpha > 0$, if $K_s = 0$, then $Y(t) = 0$. As outlined above, the assumption that phenomena such as trust, moral norms, and networks are indispensable assets for material production is commonly acknowledged in the field of behavioral economics. It is worth noting that this view dates back to the dawn of economic science. As mentioned in the review in Section 2, Adam Smith's Theory of Moral Sentiments presages some of the claims recently proposed by behavioral studies. In particular, Smith believed that there were certain virtues, such as trust and a concern for fairness, that were vital for the functioning of a market economy. He wrote about trust and reciprocity as critical foundations of the early beginnings of the market, allowing reciprocal gift exchange to emerge, and leading to trade (Ashraf et al. 2005). In our analysis, we embrace this insight and argue that the functioning of the economy itself may rely on those institutions (whether formal or informal) that the literature groups together under the common "label" of social capital (e.g. norms of trust and reciprocity, moral sanctions, newtorks of relationships, and organizations). If this is the case, then the economy's possibility of "reproducing" itself, thereby experiencing sustainable growth, depends also on its ability to foster or at least to preserve, positive endowments of social capital.

The parameter 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.

The time evolution of social capital is assumed to depend on the average social participation $\overline{s}$ and on the stock of social capital:

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

where $\dot{K}_s(t)$ indicates the time derivative of $K_s(t)$, and $1 > \delta, \eta > 0$. The exponent of K_s in the function $I(\overline{s}, K_s)$ 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 may give 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 parameter δ measures the elasticity of the "investment function" I in social capital with respect to the average social participation $\overline{s}$:

$$\frac{\frac{\partial I}{\partial \overline{s}}}{I} \overline{s} = \delta$$

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[2]. 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 $\overline{s}$ and K_s are essential for the creation of social capital. If just one of these is equal to zero, then the time evolution of social capital will be negative (i.e. there will be an erosion of the stock), 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

[2] This assumption was also used in the economic growth models analyzed by Antoci et al. (2005, 2007, 2008).

human interactions. For example, a material, highly technology 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 a substitution process can take place is given by $\rho = \frac{1}{1+\theta}$, measuring the (constant) elasticity of substitution between C and B. We will refer to the case $\theta > 0$ by saying that there is "low" substitutability between B and C . In this situation, material and relational goods are "complements". If $\theta < 0$, there is high substitutability between material and relational goods. We will refer to this case by saying that B and C are "substitutes"[3].

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 (7) coincides with the solution of the following static maximization problem:

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

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^* of s:

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

where $1 > s^* > 0$ always holds.

[3]It is well known (see e.g. Barro and Sala-i-Martin, 1999, pp. 42-46) that, 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. 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. 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.

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 (**??**)). 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 $\theta < 0$ and decreasing if $\theta > 0$.*

The proof of this proposition is straightforward.

Remember that, by assumption, $\gamma > \alpha$ holds; this implies that, when K_s increases, the time spent in social participation becomes relatively more productive with respect to that spent in the production of the private good. In such a context, the above proposition says that there is a positive correlation between s^* and K_s if $\theta < 0$ (i.e. if C and B are substitutes); in such a case, after an increase in social capital, agents devote more time to social participation in that they are willing to replace private goods with relational ones (vice-versa when K_s decreases). If $\theta > 0$, the opposite holds; in this case, after an increase in social capital, agents 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.

The parameter θ, defining the degree of substitutability between material and relational goods, is 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 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.

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:

$$\dot{K}_s = \overline{s}^{\delta} K_s - \eta K_s = \left(\frac{h K_s^{\theta \frac{\alpha-\gamma}{\theta+1}}}{h K_s^{\theta \frac{\alpha-\gamma}{\theta+1}} + 1} \right)^{\delta} K_s - \eta K_s \tag{10}$$

where $h := \left(\beta\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\theta+1}} > 0$. The basic properties of dynamics under equation (10) are illustrated by the following propositions.

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 *The stationary states of dynamics (10) 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 $\theta < 0$, then the stationary state $\overline{K}_s^0$ is locally attractive and $\overline{K}_s^1$ is repulsive (see Figure 1.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 $\theta > 0$, then the stationary state $\overline{K}_s^0$ is repulsive and $\overline{K}_s^1$ is globally attractive (see Figure 1.b). The economy cannot follow a trajectory along which K_s grows without bound.

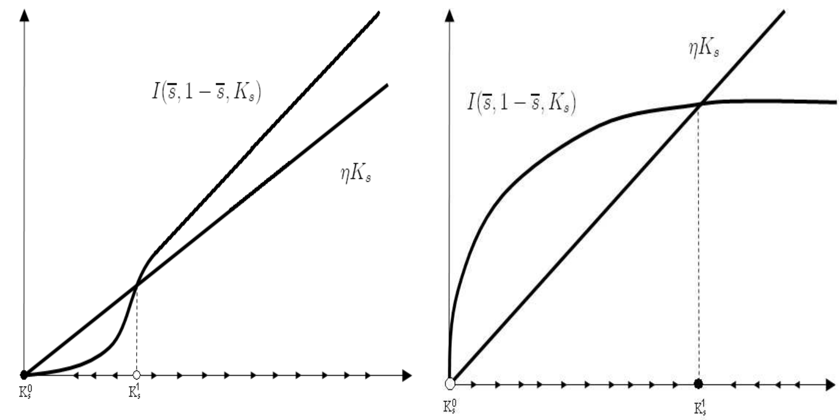


Figure 1: *(a) Dynamics in the context $\theta < 0$ (b) Dynamics in the context $\theta > 0$.*

The proof of these propositions are straightforward. According to the last proposition, the stock of social capital can follow a path of unbounded growth only if $\theta < 0$, that is, in the context where the equilibrium social participation s^* is positively correlated to K_s; this condition holds (see Proposition 1) if B and C are substitutes. Being s^*positively correlated to K_s in the case $\theta < 0$, 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[4]. The opposite holds in the context $\theta > 0$, 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.

6 Exogenous technological progress

In the framework developed in the previous section, 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 our model. 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 sector. 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 preserving social ties from cooling (this is 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 reconnecting with old friends (think for example of the ability of Facebook to refresh relationships 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 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:

$$Y(t) = [1 - s(t)]\, K_s^{\alpha}(t) T^{\pi}(t)$$

$$B(t) = s^{\beta}(t)\overline{s}^{1-\beta}(t) K_s^{\gamma}(t) T^{\psi}(t) \tag{11}$$

where T represents technological progress, growing at the exogenous rate $\mu > 0$:

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

and $\pi > 0$ and $\psi > 0$ are the elasticities of Y and B, in respect to T.
According to (12), $T(t) = T(0)e^{\mu t}$ holds.

[4] Antoci and Bartolini (1997, 1999, 2005) analyze this kind of self-enforcing mechanism in a context where private goods and open-access natural resources are substitutes. In such a context, they show that the depletion of natural resources is an engine of "undesirable" economic growth.

In this context, the time allocation choice and the accumulation dynamics of social capital are given by:

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

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

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 (see the Appendix):

$$\dot{H} = \frac{\theta}{\theta+1} H \left[(\alpha-\gamma) \left[\left(\frac{hH}{hH+1} \right)^{\delta} - \eta \right] + \mu(\pi-\psi) \right] \tag{16}$$

Since (16) is an autonomous differential equation, we can carry out a complete classification of the dynamic regimes under (16) (see the Appendix).

Proposition 4 *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, $K_s \to 0$, 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, $K_s \to +\infty$, for $t \to +\infty$.

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

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 $K_s \rightarrow 0$ or $K_s \rightarrow +\infty$ may hold, that is, K_s cannot approach a strictly positive value. The introduction of technical progress makes social participation and social capital follow significantly different dynamics. more specifically, the stock of social capital cannot converge to a positive value. This result is instead possible in the case without technical progress if $\theta > 0$, i.e. if the two goods B and C are complements. The effect of T in fact prevails on the "stabilizing mechanism" according to which, if there is no substitutability between B and C, a reduction in the stock of social capital is accompanied by a rise in social participation, due to the configuration of the individual preferences. In other words, the model shows that technical progress rules out the intermediate case where the dynamic of social capital can converge to a finite value. Figure 2 shows a qualitative representation of the four cases outlined in the above proposition. The black dots are the fixed points in the different regimes. In Case 1, H_1^* is a repulsive fixed point and 0 and infinity are attractors; in Case 2, H_2^* is the unique attractor of the system; in Case 3, infinity is the unique attractor of the system; in Case 4, 0 is the unique attractor of the system. Differently from the case without technical progress, where the stock of social capital can converge to a positive value, K_s can now tend either to 0 or to $+\infty$.

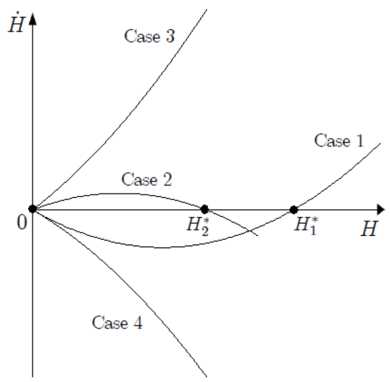


Figure 2: *A qualitative representation of the four cases outlined in proposition 4.*

It is easy to check that the previous proposition has the following corollary, which provides the necessary and sufficient conditions allowing for the existence of trajectories along which $K_s \rightarrow +\infty$:

Proposition 5 *Under dynamics (16), there exist trajectories along which* $K_s \rightarrow +\infty$ *if and only if*[5]*:*

a) $\pi - \psi > 0$ *holds and either condition (a.1) or condition (a.2) holds, where:*

a.1) $\theta < 0$, $\mu < \frac{(1-\eta)(\gamma-\alpha)}{\pi-\psi}$

a.2) $\theta > 0$, $\mu > \frac{(1-\eta)(\gamma-\alpha)}{\pi-\psi}$

b) $\pi - \psi < 0$ *and* $\theta < 0$ *hold.*

In the context (a.1), the dynamics are bi-stable, that is, $K_s \rightarrow +\infty$ *or* $K_s \rightarrow 0$ *can be observed according to the initial values of* K_s *and* T*. In the context (a.2),* $K_s \rightarrow +\infty$ *always holds whatever the (strictly positive) initial values of* K_s *and* T *are. Finally, in the context (b), bi-stable dynamics occur if:*

$$\mu < \eta \frac{\gamma - \alpha}{\psi - \pi} \tag{17}$$

If condition (17) is not satisfied, then $K_s \rightarrow +\infty$ *always holds.*

When technology has higher returns in the private sector (condition a), we have two possibilities:

(a1) if B and C are substitutes, a high growth rate of technology leads agents to replace relational with material goods. In order to preserve the stock of social capital, technical progress should not be "too fast".

(a2) if B and C are complements, in order to preserve the stock of social capital, technology should grow at a high rate.

In other words, if technical progress grows at a high rate and if $\pi - \psi > 0$ (i.e. an increase in T and K_s is accompanied by a "balanced" growth of the productivity of time spent in private and social activities), then the complementarity between the two kinds of good rules out the risk of contracting the Solaria Syndrome (i.e. of falling in the social poverty trap $K_s = 0$). By contrast, the Syndrome remains an actual risk if B and C are substitutes[6].

Condition *(b)*, holding when technology has lower returns in the private sector, is analogous to that allowing for an unbounded growth of K_s in the model without technical progress: $\theta < 0$. 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 social sector. Increases in T and K_s cause an unbalanced growth of the productivity of time spent in social activities. If B and C are complements ($\theta > 0$), then trajectories of unbounded growth of K_s are not possible. If B and C are substitutes ($\theta < 0$), then, after an increase in T and K_s, agents will devote more time to social participation because, thanks to the substitutability they prefer to replace private goods with relational ones. In this case, substitutability works as a condition for the unbounded growth of social capital. In the context of *(b)*, condition (17) means that, if technical progress grows at a high enough rate, then the risk of falling in the social poverty trap $K_s = 0$ is precluded.

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

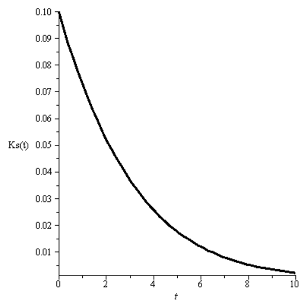
[6] This risk has been previously outlined in Antoci et al. (2005, 2007, 2008).

The scenario described by condition *(b)*, where T has higher returns in the social sector, 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 relationships. 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 contexts described in the previous proposition may thus look as "socially sustainable" development paths, along which technology and social capital accumulation balance one another in fostering the growth of the private and the social sectors of the economy.

Overall, if certain conditions hold, technical progress can give rise to 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 3a and 3b 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: $\alpha = 0.3$, $\beta = 0.1$, $\gamma = 0.52$, $\delta = 0.1$, $\eta = 0.21$, $\theta = -0.6195$, $\lambda = 0.5$, $\mu = 0.15$, $\pi = 0.9$, $\psi = 0.001$. Note that the time evolution of $U(C, B)$ exhibits an initial growth followed by a decline. At the beginning, technical progress is able to "compensate" the decline of social capital in the determination of the utility. However, such a "compensation effect" is jus temporary. After a certain period of time, T is not able to counterbalance the decrease of K_s anymore: as a result, the erosion of the stock of social capital is accompained by a fall in the well-being of individuals.



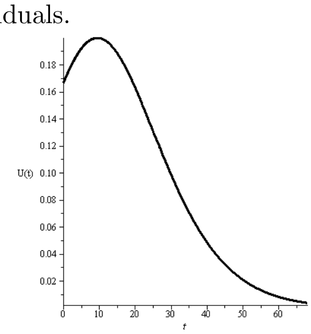


Figure 3: *(a) Time evolution of social capital (b) Time evolution of well-being.*

Figure 4 shows an example of path dependence: the stock of social capital approaches zero along the trajectory starting from $K_s(0) = 0.0025, T(0) = 1$

while it grows without bound along the that starting from $K_s(0) = 0.0043, T(0) = 1$; parameter values are: $\alpha = 0.3$, $\beta = 0.1$, $\gamma = 0.72$, $\delta = 0.1$, $\eta = 0.1$, $\theta = -0.81$, $\lambda = 0.5$, $\mu = 0.05$, $\pi = .2$, $\psi = 0.1$.

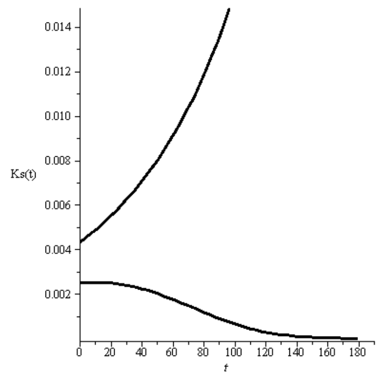


Figure 4: *An example of path dependence.*

7 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 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 $B = s^{\beta}\overline{s}^{1-\beta}K_s^{\gamma}$ and $C = (1-s)K_s^{\alpha}(t)$, 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 $\dot{K}_s = \overline{s}^{\delta}K_s - \eta K_s$ and there is not technical progress.
2. The time evolution of K_s is given by $\dot{K}_s = \overline{s}^{\delta}K_s - \eta K_s$ and, furthermore, is conditioned by exogenous technical progress T, which enters in the production functions of C and B: $C = (1-s)K_s^{\alpha}T^{\pi}$ and $B = s^{\beta}\overline{s}^{1-\beta}K_s^{\gamma}T^{\psi}$.

We have shown that, in the context (1), trajectories along which $K_s \to +\infty$ exist if and only if the condition $\theta < 0$ holds, i.e. if B and C are substitutes. In such case, the average social participation $\overline{s}$ is positively correlated with K_s: 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. However, in such a context, 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 (see Figure 1a). The opposite holds in the context $\theta > 0$, 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 (see Figure 1b).

In the scenario (2), trajectories along which $K_s \to +\infty$ can exist in both contextes $\pi - \psi > 0$ (i.e. the elasticity of B with respect to T is lower than that of Y) and $\pi - \psi < 0$. In particular, when $\pi - \psi > 0$, such trajectories exist when B and C are substitutes and technical progress is not "too fast" (condition *a.1* of proposition 5) or when B and C are complements and technology grows at a "high" rate; furthermore, when technical progress grows at a "high" rate, the complementarity between B and C rules out the risk of contracting the Solaria Syndrome, that is, of falling in the social poverty trap $K_s = 0$ (see the last part of proposition 5); by contrast, the Syndrome remains an actual risk if B and C are substitutes.

The context $\pi - \psi < 0$ is characterized by the fact that both technical progress and the accumulation of social capital cause a higher productivity increase in the social sector. Increases in T and K_s cause an unbalanced growth of the productivity of time spent in social activities. In such a context, if B and C are complements ($\theta > 0$), then trajectories of unbounded growth of K_s are not possible. If B and C are substitutes ($\theta < 0$), then, after an increase in T and K_s, agents will devote more time to social participation because, thanks to the substitutability they prefer to replace private goods with relational ones. In this case, substitutability works as a condition for the unbounded growth of social capital.

Our findings show that technology plays a key 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, we find that, in some cases, technology can work as an antidote to the destruction of human interaction feared in the Solaria metaphor. The positive role of technical progress emerges not only when T improves the relative profitability of social participation in the scenario where material goods can be replaced by relational ones but also when the benefits of technical progress mainly concern the private sector. In this scenario, technology may work as factor of preservation of the social ties of individuals in a context of growing pressure on time.

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9 Appendix

The time derivative of the variable H is:

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

Notice that the equation:

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

admits at most one stationary state with $H > 0$. Such stationary state exists if and only if:

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

and it is given by:

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

When $H \to +\infty$, the right side of (18) tends to:

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

i.e. dynamics (18), 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 (i.e. for H high enough), the following condition must hold:

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

Proposition 4 can be easily proved by taking into account of these features of dynamics (18).