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Jun-ichi Itaya

Chris Tsoukis

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Faculty of Economics and Business  
Hokkaido University  
Kita 9 Nishi 7, Kita-Ku, Sapporo 060-0809, JAPAN

# Social Capital and the Status Externality\*

Jun-ichi Itaya<sup>†</sup>

Chris Tsoukis<sup>‡</sup>

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## Abstract

This paper investigates how the presence of social capital affects the externality arising from status-seeking preference as a parable for inefficient antagonistic behavior. It is assumed that the stock of social capital is accumulating through joint social interaction between rational individuals who are forward looking. Using a differential game, we show that although the presence of social capital mitigates the tendency of overconsumption over time, social capital ends up declining to zero. It is also shown that the benefits from social capital enhance the motivation of individuals to accumulate social capital thereby leading to deter overaccumulation and thus possibly improving social welfare.

JEL classification: O40; Q33

Keywords: social capital, status externality, Markov perfect equilibrium, differential game

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<sup>†</sup>Corresponding author. Graduate School of Economics and Business Administration, Hokkaido University, Sapporo 060-0809, Japan. Tel: +81-11-706-2858; Fax: +81-11-706-4947; E-mail: itaya@econ.hokudai.ac.jp

<sup>‡</sup>Economics and Finance, Keele Management School, Darwin Building, Keele University, Staffordshire, ST5 5BG, UK; Tel: +44 (0)1782 733101; E-mail: c.tsoukis@keele.ac.uk

# 1 Introduction

Social capital is a concept with a long history in the social sciences, and the subject of a rapidly expanding literature in economics. In varying contexts, it has been shown to affect positively growth and development (Knack and Keefer 1997; Knack and Zak, 1999; Dasgupta and Serageldin, 2000; Grootaert and van Bastelaar, 2002; Putnam, Leonardi and Nanetti, 1993), institutional design and performance (Djankov, Glaeser, La Porta, Lopez-de-Silanes, and Shleifer, 2003) and financial development (Guiso, Sapienza, and Zingales, 2004). In his seminal contribution, Putnam (1993) found a correlation between measures of civic engagement and governmental quality across Italian regions. Similarly, Guiso, Sapienza, and Zingales (2004) find a correlation between civic engagement and financial development, again for Italy. LaPorta, Lopez-de-Silanes, Shleifer and Vishny (1999) find cross-country correlation between a measure of trust and judicial efficiency (positive) and government corruption (negative). But, despite the lavish attention to the concept, a precise definition has remained elusive, as we discuss below. One implication of the lack of conceptual clarity is that formal treatment of social capital is sparse in the literature, with important exceptions of course; furthermore, as a result of both conceptual ambiguity and lack of formal analysis, empirical measurement has proved difficult (Durlauf, 2002). Our overall objective in this paper is to provide an analytical framework of social capital, starting from a clear definition.<sup>1</sup>

Landmark contributions in sociology such as Coleman (1990), Putnam (1993, 2000) and Fukuyama (1997) place shared norms, beliefs and trust that facilitate economic (and wider) activity and promote efficiency, at the heart of social capital. Putnam, Leonardi, and Nanetti (1993), Bowles and Gintis (2002) and Routledge and von Amsberg (2002) define social capital as the social or governance structures that facilitate cooperation. However, defining social capital by its supposed effect (cooperation) seems like putting the cart in front of the horses; a clear definition should go first, then the effects investigated. Additionally, in some of these analyses, social capital is a by-product of exchange, social interaction or other decision such as location; there is no associated investment decision. Such a definition does not satisfy Solow's (1995) four essential criteria for a concept of capital: distinctiveness (particularly

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<sup>1</sup>Very useful surveys on social capital include Dasgupta (2003), Durlauf and Fafchamps (2005) and Guiso, Sapienza and Zingales (2012).

from human capital), measurability (in principle), and clear process of accumulation and depreciation.

In a recent attempt to define the concept more precisely. Guiso, Sapienza and Zingales (2012) define social capital as ‘... shared beliefs and values that help a group overcome the free rider problem in the pursuit of socially valuable activities.’<sup>2</sup> While plausible, this appears unduly restrictive: One may think of instances when a more general group of activities may alleviate more inefficiently negative externalities than the free rider such as status-related ‘rat races’. In the same spirit, Durlauf and Fafchamps (2005) suggest that: (a) social capital generates positive externalities for members of a group; (b) these externalities are achieved through shared trust, norms, and values and their consequent effects on expectations and behaviour; (c) shared trust, norms, and values arise from informal forms of organizations based on social networks and associations. The first two aspects of this definition are virtually identical to the Guiso et al. (2012) definition; requirement (c), however, appears a little restrictive in that beneficial collective action, even informal and unintended, may happen in the wider community, outside of such associations.<sup>3</sup>

A further point that requires clarification is the distinction between a pure social capital and socially-related but privately-owned capital. Social capital is often defined in such a way that it entails a private as well as a social benefit via various externalities. E.g., Glaeser, Laibson and Sacerdote (2002, p. F439) define social capital as ‘social characteristics that yield a market as well as non-market yield’; as they themselves acknowledge however, such social skills (to use the everyday term) include those of ‘... the stereotypical used car salesman who has lots of individual social capital (i.e., he’s good at selling lemons to naïve consumers), but who generates little net social capital because of his negative social capital externalities’. Thus, this type of skill should more appropriately be considered as a socially-related, private skill or form of human capital; social capital properly defined should be closer to what Glaeser et al. (2002) call ‘aggregate’ social capital, which nets out all the externalities from individual capital. Likewise, membership in an organization or network, a common definition of social capital, that confers a private benefit and perhaps positive externalities among the group but

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<sup>2</sup>To distinguish from other approaches, they call this ‘civic capital’; we shall use the more standard term.

<sup>3</sup>Element (c) may in fact impart an element of circularity in so far as the defining characteristic of networks is shared norms.

little on no wider social benefit, should also be excluded from a proper definition of social capital for the same reasons.

In the light of the above, we propose that any definition should start from the words themselves: social and capital: capital formed through costly (in an opportunity-cost sense) investment, e.g., education; but it may well be intangible, such as shared norms, beliefs, networks and institutions; and social, contributed to by many but not owned by anyone in particular. A further point concerns the exact nature of the benefit that accrues at societal level. Activities such as communal policing and cleaning of streets, while socially beneficial, are arguably more in the nature of public services arising from voluntary contributions (of time and effort) rather than taxation. So, we define social capital to be all community-related formal and informal engagement, beliefs, values, norms and practices that help society achieve Pareto-superior outcomes and that require resources to build. Examples may include contributing to charity, ethical behaviour and norms such as politeness and mutual help, environmentally friendly norms and practices, quality of governance and institutions (Tabellini, 2008b), etc. All these require investment such as formal and informal education and/or personal involvement and time. The beneficial effects arise firstly from the alleviation of inefficiencies related to status-seeking, conspicuous, corrupt or aggressive behaviour, other rat races, free-riding, etc. Second, social capital may confer utility directly: Helliwell, Akin, Shiplett, Huang and Wang (2017) find that a higher social capital is associated with a greater subjective well-being.<sup>4</sup> Indeed, one may think of plausible reasons why there may be utility derived directly from social capital in the form of a lower crime rate or greater social ties, mutual trust and cooperation, reducing monitoring costs, reducing contractual costs and so on, in addition to the mitigation of the negative externalities.

Guided by this definition, we propose a novel formal framework to model social capital as a community-related state variable, formed through costly investment, that alleviates the social inefficiencies associated with negative externalities. Our model rectifies the weaknesses over existing literature that have been identified above. The model is a very simple macro setup with flexible labour; it is static except the evolution of social capital that induces dynamics. To capture inefficiencies, the utility function exhibits a status motive (alternatively

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<sup>4</sup>This is an effect akin to the 'warm glow' type of benefit from giving (Andreoni, 1990) except it stems from the level of social capital rather than the individual contribution to it.

known as ‘keeping up with the Joneses’) that induces zero-sum behaviour (see, e.g., among many others: Alonso-Carrera, Caballé and Raurich, 2004; Alvarez-Cuadrado, Monteiro and Turnovsky, 2004; Futagami and Shibata, 1998; Tsoukis, 2007; Tournemaine and Tsoukis, 2009). Thus, social capital is an aggregate state variable that alleviates the status motive and its concomitant sub-optimal effects. But the emphasis on status is only for analytical convenience; very similar behaviour and effects includes corruption and aggression, ostentatious behaviour and rat races, as well as free-riding. Our framework is perfectly compatible with this wider interpretation, in which social capital restrains individuals from any unsociable (i.e., inefficient) behaviour. In one version of our setup, we allow for direct personal satisfaction from social capital as well as its effects in alleviating negative externalities. Analytically, investment in social capital relies on individual contributions of time; this time is costly in an opportunity-cost sense and, implicitly, enhances social activities such as formal and informal education. Social capital is also subject to gradual depreciation. Thus, it satisfies all of Solow’s (1995) criteria. We show that such a concept yields novel insights, thus satisfying the additional criterion of usefulness.

Existing formal treatment of the concept of social capital is rather sparse. In an elegant early contribution, Glaeser, Laibson and Sacerdote (2002) model the investment-into-social capital decision in an explicitly optimising way; a clear progress over earlier analyses. However, as alluded to above, their interface between individual and aggregate social capital is problematic as they fail to incorporate the externalities. Our concept of social capital clarifies that; another improvement of our setup is that it considers the feedback effects from non-atomistic individual behaviour to the aggregate. Routledge and von Amsberg (2002) offers a careful game-theoretic analysis of social capital-as-cooperation; the problem with this approach has been mentioned above. In a model where growth arises from productivity changes that require labour re-allocation, social capital has welfare effects. Without social capital, maximum growth arises from frictionless re-allocation, yet this re-allocation will involve less likelihood of stable (repeated) trade relationships and therefore cooperation is harder to sustain. Since social capital is defined as the sustenance of cooperation, welfare may be higher with less labour mobility. Without calling it social capital, Tabellini (2008) models the willingness to cooperate which develops from the costly education by parents to their children in order for the latter to acquire more cooperative values. This is a complementary approach to

ours in that there is ‘something’ that is sustained by costly investment and that helps society achieve more efficient outcomes; Tabellini (2008) calls it cooperation, we call it social capital. Varvarigos and Xin (2015) also presents a formal framework which is however more narrowly focused on the theme of trust.<sup>5</sup> Closer to the spirit of our analysis, Chou (2006) presents a model in which social capital facilitates standard human capital formation. Interestingly, this paper shows that there is a possibility of a poverty trap with little social capital and development. Poverty traps is a wide-ranging theme in macroeconomics and growth where lots of avenues have been explored but rather little convergence seemed to have been reached. We contribute to this theme by showing conditions under which we remain trapped in situations of low social capital and welfare or conditions under which we break out of such a deadlock.

Methodologically, our framework relies on dynamic non-cooperative game theory and models the formation of social capital as a Markov Nash equilibrium. This allows not only for the status-related externalities to be incorporated but also for the temptation to free-ride to be taken into account. This is an improvement over previous optimising analyses in that the interface between the individual decisions of the decision to contribute to invest for social capital and the aggregate outcome is made explicit; thus, externalities from free riding are explicit taken into account alongside those related to status and other distortions. Additionally, our framework allows agents to be of a finite number, therefore non-atomistic, and to consider the dynamic effects of their strategic behaviour on the aggregate outcome in a forward-looking manner. As such, our framework resolves the tension between the traditional individual-optimising approach of economics and more sociological analyses that view the community level as the appropriate decision-making unit for social capital (see Glaeser, Laibson and Lacerdote, 2002).

Thus our contribution is a formal analysis of social capital, in particular it contribution to the alleviation of inefficient antagonistic behaviour and associated negative externalities. Based on the general idea that social capital is accumulated through time in a situation where social capital is in a purposeful manner with each other in informal and formal meeting, we

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<sup>5</sup>While trust may arguably be a component of social capital, it is characterised by reciprocity; thus, trust is either shared widely or not. One may think of examples of social capital in such a way that one person may contribute to it while another may not, thus, reciprocity is not a necessary feature. In much of our analysis below, we shall assumed symmetry, thus reciprocity is imposed.



model the formation of social capital using dynamic games, in particular, differential games which enable us to capture the dynamic strategic considerations among forward-looking individuals. In other words, social capital may well arise as a by-product of such social interaction among a *finite* number individuals who are aware of each other. More specifically, the use of differential games highlights the following facts: (i) social capital is a stock variable in such a way that it is an accumulated variable from which generates the flow of benefits over time; thereby creating intertemporal externalities: and (ii) interaction between individuals repeatedly occurs in different environments where the level of social capital varies through time. Hence, we explicitly model a situation in which each individual explicitly takes account of the strategic responses of other individuals at each moment in time, which stands a sharp contrast with the previous dynamic models of social capital formation such as Glaeser, Laibson and Sacerdote (2002) in which *atomistic* agents undertake social capital accumulation, taking the aggregative social capital as exogenously given, and ignoring the feedback effect of optimal investment decisions regarding social capital made by other individuals. Although their treatment of social capital accumulation is the same as those of the traditional macroeconomic models of investment in physical and human capital, their modeling strategy based on reduced-form representations of social capital would not provide a satisfactory way of exposing the fact that there are strong interpersonal complementarities of social capital accumulation across individuals or the members of peer groups have positive externalities each other.

We derive several results. The first result is that, in the case where social capital alleviates externalities but does not confer direct utility of the ‘warm glow’ type, there exist (possibly, a continuum of) MPE strategies which almost always causes overconsumption compared to the Pareto-efficient consumption level. Secondly, the most interesting result of this analysis, is that such overconsumption inevitably leads social capital to zero. In this case, the society almost always fails to accumulate social capital, and it stays in a poverty trap in the sense that the unchecked negative externalities cause net welfare to be low. In other words, a situation akin to a prisoners’ dilemma arises. This pessimistic result is lifted when ( a necessary condition) social capital enters directly individuals’ utility function. According to our third result, if the degree of the disutility of labor takes intermediate values, getting out of a poverty trap is possible.

A further theme to which our paper contributes is the ‘social multiplier’ (Scheinkman, 2008; Glaeser, Sacerdote and Scheinkman, 2003). Social multiplier is said to arise when social interactions of various types give rise to a total effect of fundamentals that is greater than if such social interactions did not exist. An application is social capital which is an embodiment of social interactions both directly (as it is communally built) and indirectly (as it alleviates the effects of externalities) in the present model.

The organization of the paper is as follows. The next section describes the basic model, and then characterizes the dynamics of the model. Section 3 conducts the same analysis by extending the basic model to include peculiar benefits from social capital. Section 4 performs an analysis regarding welfare comparison between the command economy and the decentralized economy. Section 5 concludes the paper with a discussion and suggestions for future research. Additional mathematical proofs will be given in Appendices A and B.

## 2 The Model

There are  $n$  ( $\geq 2$ ) individuals. The instantaneous utility of individual  $i$  depends positively on consumption,  $c_i$ , and social status  $c_i/\bar{c}$ , where  $\bar{c} = (\sum_{j=1}^n c_j)/n$  represents average consumption. The objective function of individual  $i$  is a discounted-sum of utilities over an infinite-time horizon:

$$u_i = \int_0^{\infty} \left[ \log c_i - \beta l_i + (1 - \theta_i(S)) \log \left( \frac{c_i}{\bar{c}} \right) \right] e^{-\rho t} dt, \quad \rho > 0, \quad i = 1, 2, \dots, n, \quad (1)$$

where the function  $\log(c_i/\bar{c})$  captures the status externality, and  $\beta$  represents the weight on the disutility arising from labor supply. Specification of the second term in (1) would capture the fact the utility of each individual increases in the utility that the other individuals assign to her or his achievement in excess of average.<sup>6</sup> In addition, the variable  $\theta_i(S)$  represents the perception of social capital by individual  $i$ :  $\theta_i(S) : R_+ \mapsto [0, 1]$ ; that is, the extent to which the status externality is internalized due to the spirit of social capital, and thus  $1 - \theta_i(S)$

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<sup>6</sup>Although it appears that larger  $S$  reduces the utility in (1), it is not a case because we will show that the presence of status-seeking preferences leads individuals to overconsumption which in turn deteriorates their well-being; however, the tendency of overconsumption which would be larger than the Pareto-efficient level is gradually weakened as a result of the accumulation of social capital, thereby generating positive externalities on individual utility.

represents the weight put on status-seeking motive.

Individuals decide at each point in time how much they engage in social interaction as well as how much to consume. Their choices are constrained by a time constraint. Consumption is also constrained by income, which is earned from working at a wage rate  $w$  according to the following flow budget constraint for individual  $i$  at each point in time:

$$c_i = wl_i,$$

while the time constraint is given by

$$1 \geq l_i + a_i,$$

where  $a_i$  is the time allocated to social activities which contribute to accumulating the stock of social capital over time and  $l_i$  is the amount of labor supply. For notational simplicity, we assume not only that the relative price between private consumption and leisure (i.e., the wage rate  $w$ ), which is set equal to 1, but also that the time endowment is also normalized to be one through time. As a result, combining both constraints yields

$$c_i = 1 - a_i. \tag{2}$$

The aggregate stock of social capital will continuously change over time according to

$$\dot{S} = S(\sum_{i=1}^n a_i) - \delta S, \tag{3}$$

where  $\delta$  is a constant depreciation rate of social capital ( $0 < \delta < 1$ ). The emergence of  $S$  in the production of social capital reflects the fact that the existing social capital stock has spillover effects on the building of social capital.

Each individual maximizes the intertemporal utility  $u_i$  in (1) by selecting the time paths of  $c_i$  and  $a_i$  subject to (2) and the given initial level of social capital,  $S_0 (\geq 0)$ , taking into account the others' strategies  $a_j$  ( $j = 1, 2, \dots, n : j \neq i$ ). We define a subgame perfect Nash equilibrium of this  $n$ -player differential game denoted by  $\Gamma(S_0, 0)$  in the next subsection, where  $S_0$  represents a historically given initial stock of social capital.

## 2.1 Solution Concept

We solve the differential game  $\Gamma(S_0, 0)$  using the notion of a stationary Markov Perfect Equilibrium (MPE), which is appealing because, in ruling out all direct strategic interactions, it allows use of optimal control tools. To state this concept of equilibrium in a mathematically rigorous way, we reproduce a series of definitions given by Dockner et al. (2000) with notational modifications:

**Definition 1** (Dockner et al., 2000, Definition 3.1). *A control path  $c_i : [0, \infty) \mapsto \mathbb{R}_+$  is **feasible** for the game  $\Gamma(S_0, 0)$  if the initial value problem defined by (1) – (3) has a unique, absolutely continuous solution  $S(\cdot)$  such that the constraints  $S(t) \in \mathbb{R}_+$  and  $c_i(t) \in [0, 1]$  hold for all  $t$  and the integral in (1) is well defined.*

As the game  $\Gamma(S_0, 0)$  is stationary, we can focus on equilibria supported by stationary strategies. For analytical simplicity, we further restrict ourselves to stationary Markov strategies throughout the paper.

**Definition 2** (Dockner et al., 2000, p.97). *A stationary Markov strategy is a mapping  $\phi^i : \mathbb{R}_+ \mapsto [0, 1]$ , so that the time path of the control is  $c_i(t) = \phi^i(S(t))$ .*

Hence, stationary Markov strategies are functions only of the current state. Then we can define:

**Definition 3** *The  $n$ -tuple of functions  $(\phi^1, \phi^2, \dots, \phi^n)$  is a stationary Markov Nash equilibrium if for each  $i \in \{1, 2, \dots, n\}$  an optimal control path  $c_i(t)$  of the problem  $\Gamma(S_0, 0)$  exists and is given by the stationary Markov strategy  $c_i(t) = \phi^i(S(t))$ .*

We use the further strengthening of Markov Nash equilibrium, that is, subgame perfectness, to characterize an equilibrium path:

**Definition 4** (Dockner et al., 2000, Definition 4.4). *The  $n$ -tuple of functions  $(\phi^1, \phi^2, \dots, \phi^n)$  is a Markov Nash equilibrium of the game  $\Gamma(S_0, t)$ . The Markov Nash equilibrium is Markov perfect equilibrium (MPE) if for each  $(S, t) \in \mathbb{R}_+ \times [0, \infty)$ , the subgame  $\Gamma(S, t)$  admits a Markov Nash equilibrium  $(\psi^1, \psi^2, \dots, \psi^n)$  such that  $\psi^i(\hat{S}, s) = \phi^i(\hat{S}, s)$  for all  $i \in \{1, 2, \dots, n\}$  and all  $(\hat{S}, s) \in \mathbb{R}_+ \times [t, \infty)$ .*

Since the subgame  $\Gamma(S, t)$  is stationary,  $\Gamma(S, 0) = \Gamma(S, t)$  and thus all stationary Markov Nash equilibria are MPE.

The model described above is a differential game in which each player's strategies are its consumption and social interaction (or labor supply), which is measured by the time devoted to social activities, while the state variable of the game is the aggregate stock of social capital  $S$ . Since we focus on the (stationary) Markov-perfect equilibrium (MPE), we assume that each agent's strategies,  $c_i$  and  $a_i$ , are functions of the current stock level of aggregate social capital,  $S$ , alone. This means that the value function of the  $i$ -th agent's optimization problem at time  $t$  can be written as

$$V_i(S_t) \equiv \max \int_t^\infty e^{-\rho(\tau-t)} u_i(c_i(\tau), l_i(\tau), S_t) d\tau. \quad (4)$$

We make the following assumption:

**Assumption 1:** The value function of individual  $i$ ,  $V_i(S) = \max_{\{c_i(\cdot), l_i(\cdot)\}} J_{\phi^i}^i(c_i(\cdot), l_i(\cdot))$ :  $R_+ \rightarrow R$ , is locally Lipschitz continuous.

## 2.2 Candidate Markov Perfect Equilibrium Strategies

The value function (4), after substitution of  $l_i = c_i$  in (1), satisfies the Hamilton-Jacobi-Bellman (HJB) equation such as

$$\rho V_i(S) = \max_{\{c_i\}} \left\{ \log c_i - \beta c_i + (1 - \theta_i(S)) \log \left( \frac{c_i}{C/n} \right) + V_i'(S) [S \sum_{j=1}^n (1 - c_j) - \delta S] \right\} \quad (5)$$

for all  $t \geq 0$ , where  $C \equiv \sum_{j=1}^n c_j$ . In solving the maximization problem defined in the right-hand-side of (5) at each moment in time, the  $i$ -th individual takes the other players' strategies,  $\{c_j\}_{j \neq i}$  ( $j = 1, 2, \dots, n$ ), as given. The first-order conditions for  $i$ 's choice of consumption are given by

$$\frac{1}{c_i} - \beta + (1 - \theta_i(S)) \frac{1}{c_i/C} \frac{\sum_{j=1, j \neq i}^n c_j}{C^2} - V_i'(S) S \begin{cases} = 0 & \implies c_i \in (0, 1], \\ > 0 & \implies c_i = 1. \end{cases} \quad (6)$$

According to (6), each individual, when choosing  $c_i$ , trades the marginal utility gains from an increase in current consumption and the associated status-seeking consumption against the sum of the utility loss from increased labor supply and the marginal loss in the discounted value of the future stream of *positive* externalities arising from the social capital stock in such

a way that the accumulation of social capital stock prevents from excessive consumption. If the marginal utility from an increase in current consumption is larger than the payoff loss implied by the decrease in  $a_i$  for all levels of  $c_i \in (0, 1]$ , then  $i$  will rationally devote all resources to consumption. However,  $i$  never chooses  $c_i = 0$  due to the property of logarithm utility functions. The higher the disutility of labor (i.e.,  $\beta$ ), the lower the labor supply; consequently, instantaneous consumption immediately falls through the budget constraint (2), while instantaneous consumption is also stimulated by the presence of status-seeking competition which is captured by the term  $\frac{1}{c_i/C} \frac{\sum_{j=1, j \neq i}^n c_j}{C^2}$ . In addition, the accumulation of social capital diminishes the *positive* externality of relative consumption on its own consumption, which is captured by  $1 - \theta S$ , thereby depressing consumption, while it generates the intertemporal externality captured by the term  $V'(S)S$ , which may increase or decrease consumption depending on the sign of  $V'(S)$ .

To get a closed-form solution, we have to impose a special form on the function  $\theta_i(S)$  such as

$$\theta_i(S) = \begin{cases} \theta_i S & \text{if } S < \bar{S}_i, \\ 1 & \text{if } \bar{S}_i \leq S, \end{cases} \quad (7)$$

where  $\bar{S}_i = 1/\theta_i$ . We call  $\bar{S}_i$  “a satiation level of the social capital stock” perceived by individual  $i$ .

Equation (6) gives the MPE solutions which are expressed as  $\{c_i(S)\}$  for  $i = 1, 2, \dots, n$ . Substituting these optimal solutions back into the HJB equation (5) associated with agent  $i$ , together with (7), we obtain

$$\rho V_i(S) = \log c_i(S) - \beta c_i(S) + (1 - \theta_i S) \log \left( \frac{c_i(S)}{C(S)/n} \right) + V_i'(S) [S \sum_{j=1}^n (1 - c_j(S)) - \delta S]. \quad (8)$$

By the use of the envelop theorem, we find that differentiating both sides of (8) with respect to  $S$  gives

$$\begin{aligned} \rho V_i'(S) &= \frac{c_i'(S)}{c_i(S)} - \beta c_i'(S) - \theta_i \log \left( \frac{nc_i(S)}{C(S)} \right) + (1 - \theta_i S) \cdot \\ &\frac{C(S)}{c_i(S)} \frac{c_i'(S) C(S) - c_i(S) \sum_{j=1}^n c_j'(S)}{[C(S)]^2} + V_i''(S) [S \sum_{j=1}^n (1 - c_j(S)) - \delta S] \\ &+ V_i'(S) [\sum_{j=1}^n (1 - c_j(S)) + S \sum_{j=1}^n (-c_j'(S)) - \delta]. \end{aligned} \quad (9)$$

Since we have started our analysis assuming identical individuals and since the state equation (3) is symmetric with respect to their controls, a natural focus is placed on symmetric equilibria. The symmetry assumption allows us to drop the subscript  $i$  in the subsequent discussion, and we will suppress this index unless strictly necessary for expositional clarity. Since under the assumption of symmetry  $\log(C(S)/nc(S)) = 0$  (recalling  $C(S) = nc(S)$ ) and  $c'(S)nc(S) - c(S)nc'(S) = 0$ , we obtain

$$\begin{aligned} \rho V'(S) &= \left[ \frac{1}{c(S)} - \beta \right] c'(S) + V''(S) [Sn(1 - c(S)) - \delta S] \\ &\quad + V'(S) [n(1 - c(S)) - Snc'(S) - \delta]. \end{aligned} \quad (10)$$

After the tedious manipulation, we can rewrite (10) as follows (see Appendix A):

$$\begin{aligned} c'(S) &= -\frac{1}{S} \cdot \\ &\frac{\rho \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n-1}{n} \right] + \theta \frac{n-1}{n} S [n(1 - c(S)) - \delta]}{\frac{1}{c(S)} [(n - c(S)) - \delta] \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n-1}{n} \right] + (1 - \theta S) \frac{n-1}{n} + \beta [n(1 - c(S)) - \delta]}. \end{aligned} \quad (11)$$

### 2.3 Dynamics and Steady State

We will draw the representatives of Markov strategies in a control and state space in order to characterize qualitative solutions to the nonlinear differential equation (11). The solutions satisfying (11) are only candidates and, in some cases, many of them do not qualify for a MPE. Those solutions must pass further tests to qualify for a MPE satisfying the properties stated later. To stress the candidate status, we introduce an additional notation,  $\phi(S)$ , instead of  $c(S)$ . Let us first denote by  $C_2$  the loci where  $\phi'(S)$  goes to plus/minus infinity, and by  $C_3$  the loci where  $\phi'(S)$  equals zero in the  $(S, c)$  space:

$$\begin{aligned} C_1 &:= \{(S, c) : \dot{S} = Sn(1 - \phi(S)) - \delta S = 0\}, \\ C_2 &:= \{(S, c) : \phi'(S) \rightarrow \pm\infty\}, \\ C_3 &:= \{(S, c) : \phi'(S) = 0\}. \end{aligned} \quad (12)$$

First, we can obtain the steady state locus  $C_1$  by setting  $\dot{S} = 0$ ; that is,

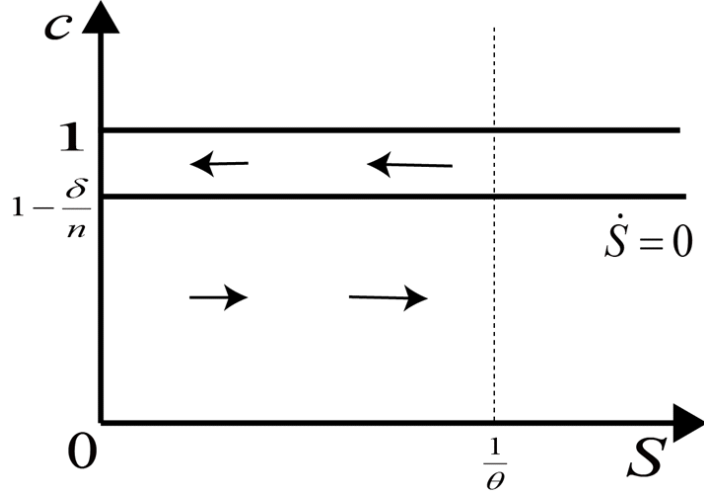


Figure 1: Steady state locus

$$c = 1 - \frac{\delta}{n}, \quad (13)$$

which implies that the steady-state locus  $C_1$ , denoted by  $\dot{S} = 0$  in Fig. 1, is a horizontal line at  $c = 1 - (\delta/n)$  in the  $(S, c)$  space. The arrows illustrated in Fig. 1 indicate that for initial values of  $\phi(S)$  above the steady state locus,  $c = 1 - (\delta/n)$ , the social capital stock is declining in time, while for those of  $\phi(S)$  below the steady state locus the social capital stock is increasing in time. It is also important to note that there is an upper bound on  $S$  (i.e.,  $S \leq (1/\theta)$ ), as illustrated by the dotted vertical straight line at  $1/\theta$  in Fig. 1.<sup>7</sup> Beyond this upper bound, there is no incentive for every individual to accumulate more social capital, because further social capital accumulation reduces utility.

Next, by setting the denominator in (11) equal to zero, we can obtain the locus of the curve  $C_2$ :

$$\frac{1}{c} [(n - c) - \delta] \left[ 1 - \beta c + (1 - \theta S) \frac{n - 1}{n} \right] + (1 - \theta S) \frac{n - 1}{n} + \beta [n(1 - c) - \delta] = 0, \quad (14)$$

which we call “the non-invertibility locus” following Rowat (2007). After some manipulation,

<sup>7</sup>Since we have made the assumption of symmetry, the satiation levels of the social capital capital perceived by all individuals are common among them, so that  $\bar{S}_i = \bar{S}$  for  $\forall i$ .



we can rewrite (14) as follows:

$$\beta c^2 (1 - n) - c + (n - \delta) \left[ 1 + (1 - \theta S) \frac{n-1}{n} \right] = 0, \quad (15)$$

whose solutions for  $c$  are given by  $c \geq 0$ :

$$c = \frac{\sqrt{1 + 4\beta (n-1) (n-\delta) \left[ 1 + (1 - \theta S) \frac{n-1}{n} \right]} - 1}{2\beta (n-1)}, \quad (16)$$

which entails that

$$\begin{aligned} \lim_{S \rightarrow 0} c &= \frac{\sqrt{1 + 4\beta (n-1) (n-\delta) \frac{2n-1}{n}} - 1}{2\beta (n-1)} \begin{matrix} \geq \\ < \end{matrix} 1, \text{ and} \\ \lim_{S \rightarrow 1/\theta} c &= \frac{\sqrt{1 + 4\beta (n-1) (n-\delta)} - 1}{2\beta (n-1)} > 0. \end{aligned} \quad (17)$$

An important point is to be noticed that if the solution curve of  $\phi(S)$  crosses the curve  $C_2$ , it becomes discontinuous at this intersection point; consequently, it is ruled out as a solution (see the next subsection in further details).

Inspection of (16) further reveals not only that the curve  $C_2$  may cross the vertical axis above or below the budget line  $c = 1$  because

$$\frac{\sqrt{1 + 4\beta (n-1) (n-\delta) \frac{2n-1}{n}} - 1}{2\beta (n-1)} - 1 \begin{matrix} \geq \\ < \end{matrix} 0 \text{ if and only if } \beta \begin{matrix} \leq \\ \geq \end{matrix} \frac{(n-\delta)(2n-1) - n}{n(n-1)}, \quad (18)$$

but also that the curve  $C_2$  may cross the vertical axis above or below the steady state line  $1 - (\delta/n)$  because

$$\frac{\sqrt{1 + 4\beta (n-1) (n-\delta) \frac{2n-1}{n}} - 1}{2\beta (n-1)} - \left( 1 - \frac{\delta}{n} \right) \begin{matrix} \geq \\ < \end{matrix} 0 \text{ if and only if } \beta \begin{matrix} \leq \\ \geq \end{matrix} \frac{2n}{n-\delta}. \quad (19)$$

It can also be verified that the curve  $C_2$  always crosses the upper boundary  $S = 1/\theta$  below the budget line  $c = 1$  because

$$\frac{\sqrt{1 + 4\beta (n-1) (n-\delta)} - 1}{2\beta (n-1)} - 1 < 0, \quad (20)$$

while the curve  $C_2$  may cross the upper boundary  $\bar{S} = 1/\theta$  below or above the steady state line  $1 - (\delta/n)$  because

$$\frac{\sqrt{1 + 4\beta (n-1) (n-\delta)} - 1}{2\beta (n-1)} - \left( 1 - \frac{\delta}{n} \right) \begin{matrix} \geq \\ < \end{matrix} 0 \text{ if and only if } \beta \begin{matrix} \leq \\ \geq \end{matrix} \frac{n}{n-\delta}. \quad (21)$$

Taking into account of (18), (19), (20) and (21) in conjunction with the following facts:

$$\begin{aligned}\frac{(n-\delta)(2n-1)-n}{n(n-1)} - \frac{n}{n-\delta} &= \frac{n^3 - 4n^2\delta - n^2 + 2n\delta^2 + 3n\delta - \delta^2}{n(n-1)(n-\delta)} \geq 0, \\ \frac{(n-\delta)(2n-1)-n}{n(n-1)} - \frac{2n}{n-\delta} &= \frac{-\delta(\delta - 3n + 4n^2 - 2n\delta)}{n(n-1)(n-\delta)} < 0, \\ \frac{n}{n-\delta} - \frac{2n}{n-\delta} &< 0, \text{ and} \\ \frac{2n-1}{n} - \frac{n}{n-\delta} &= \frac{n^2 - (2\delta+1)n + \delta}{(n-\delta)n} \geq 0,\end{aligned}$$

we can draw several geometric representations for the curve  $C_2$  such as Figs. 2 – 8, corresponding to various parameter values of  $n$ ,  $\beta$  and  $\delta$ .

On the other hand, the locus  $C_3$  is obtained by setting the numerator in (11) equal to zero. Solving it for  $c$  gives the following locus:

$$c = \frac{(n-\delta-\rho)\theta\frac{n-1}{n}S + \rho\frac{2n-1}{n}}{\rho\beta + \theta(n-1)S}, \quad (22)$$

with

$$\lim_{S \rightarrow 0} c = \frac{2n-1}{\beta n}, \quad \lim_{S \rightarrow \infty} c = (n-\delta-\rho)\frac{1}{n} < 1, \quad \text{and} \quad \lim_{S \rightarrow \frac{\rho\beta}{\theta(n-1)}} c = \infty.$$

Taken together, it turns out that the nonlinear curve  $C_3$  is an *orthogonal hyperbolic curve* in the  $(S, c)$  space which intersects with the vertical axis at  $\frac{2n-1}{\beta n}$ , as illustrated in Figs. 2 – 8. Note, moreover, that the intercept of the curve  $C_3$  lies above (below) the intercept of the budget line  $c = 1$  on the vertical axis if  $\beta < \frac{2n-1}{n}$  ( $\beta > \frac{2n-1}{n}$ ) because

$$\frac{2n-1}{\beta n} - 1 = \frac{(2-\beta)n-1}{\beta n} \geq 0 \text{ if and only if } \beta \leq \frac{2n-1}{n},$$

while the curve  $C_3$  crosses the vertical axis below (above) the steady state line (i.e.,  $c = 1 - \frac{\delta}{n}$ ) if  $\beta > \frac{2n-1}{n-\delta}$  ( $\beta < \frac{2n-1}{n-\delta}$ ) because

$$\frac{2n-1}{\beta n} - \left(1 - \frac{\delta}{n}\right) = \frac{2n - n\beta + \beta\delta - 1}{\beta n} \geq 0 \text{ if and only if } \beta \leq \frac{2n-1}{n-\delta}.$$

Lastly, the curve  $C_3$  crosses the line  $1/\theta$  above (below) the steady state line if  $\beta < \frac{n}{n-\delta}$  ( $\beta > \frac{n}{n-\delta}$ ), because

$$\frac{(n-\delta-\rho)\frac{n-1}{n} + \rho\frac{2n-1}{n}}{\rho\beta + (n-1)} - \left(1 - \frac{\delta}{n}\right) = \rho \frac{-(n-\delta)\beta + n}{[\rho\beta + (n-1)]n} \geq 0 \text{ if and only if } \beta \leq \frac{n}{n-\delta}.$$

Collecting the arguments discussed so far, we draw several geometric representations for the curves  $C_2$  and  $C_3$ , depending on the combinations of various parameter values of  $\beta$ ,  $n$  and  $\delta$ . Two remarks are made in order. First, based on the information regarding signs of (11) which are determined according to the respective regions divided by the curves  $C_2$  and  $C_3$ , together with the signs indicated by Fig.1, we can construct several phase diagrams indicating how the variables  $c$  and  $S$  move as illustrated in Figs 2 – 8.<sup>8</sup> Second, it is important to note that *not* all strategies satisfying (11), which are drawn in these figures, are solution curves. In the next subsection, we will provide further conditions to pin down the MPE strategies characterizing optimal consumption paths.

## 2.4 Refining Candidate Strategies

Unfortunately, not all interior strategies satisfying the HJB equation (5) are qualified as MPE strategies defined in Definition 4. Dockner et al. (2000) have provided sufficiency conditions for the existence of MPE. So we have to test whether those candidate strategies satisfy the sufficiency conditions in Theorem 4.1 of Dockner et al. (2000).

The solution paths must satisfy the following **three** requirements: The first requirement is that the strategies must be defined over the *entire* feasible state space (i.e.,  $S \in [0, 1/\theta]$  in the present model) and not only for its subset. Rowat (2006) claims that we have to take the definition of subgame perfection *seriously*, as long as we cannot explain how an initial

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<sup>8</sup>At this point, it may be worthy pointing out whether the intercept of curve  $C_2$  may be greater or less than that of curve  $C_3$ . To identify this, we take the difference of their intercepts to yields

$$\begin{aligned} & \frac{\sqrt{1 + 4\beta(n-1)(n-\delta)\frac{2n-1}{n}} - 1}{2\beta(n-1)} - \frac{2n-1}{\beta n} \\ = & \frac{\sqrt{1 + 4\beta(n-1)(n-\delta)\frac{2n-1}{n}} - 1 - 2(2n-1)\left(1 - \frac{1}{n}\right)}{2\beta(n-1)}, \end{aligned}$$

whose numerator can be manipulated by squaring both sides of the above expression to yield:

$$\begin{aligned} & 1 + 4\beta(n-1)(n-\delta)\frac{2n-1}{n} - \left[1 + 2(2n-1)\left(1 - \frac{1}{n}\right)\right]^2 = \\ & 4(2n-1)\frac{1}{n}(n-1)\left[\beta(n-\delta) - \left(2n-2 + \frac{1}{n}\right)\right] \geq 0 \text{ if } \beta \geq \frac{2(n-1) + (1/n)}{n-\delta}n. \end{aligned}$$

The above result implies that as long as  $\beta > \frac{2(n-1) + (1/n)}{n-\delta}$ , the intercept of the curve  $C_2$  is greater than that of the curve  $C_3$ ; otherwise, the opposite holds.

condition of the state variable was reached in the first place. To show how this requirement is used to refine candidate strategies, let us take up Fig. 2, which displays representatives of those integral curves that are categorized into three typical types of the families of strategies designated by the integral curves  $\phi_j$ ,  $j = 1, 2$ , and  $\phi^*$ . The arrows attached those integral curves indicate the evolution of  $S$  over time. Applying the first requirement, the family of strategies  $\phi_2$  can be ruled out, because those *interior* solutions do not cover the whole range of  $S$  as seen in Fig. 2. Nevertheless, it may be possible to extend the families of those strategies by patching with the corner strategy  $\phi = 1$  to the entire domain of  $S$  *when those strategies hit the boundary*  $c = 1$ , as Rowat (2004) did. To check this possibility, consider a case where the candidate interior strategy hits the boundary line  $c = 1$ . We can show that the resulting patched strategy could cover the entire domain of the state variable  $S$ , **only if** the interior strategy  $\phi^*$  is connected with the corner strategy  $\phi = 1$  at the points lying within the appropriate range indicated by the following lemma:

**Lemma 1** *The corner strategy  $\phi = 1$  is not a MPE strategy if the value function (B.2) (see Appendix B) possesses a non-zero constant of integration and satisfies  $\phi(0) = 1$ . The corner strategy  $\phi = 1$  is a MPE strategy if the value function (B.2) possesses a zero constant of integration and the domain of the state variable is given by  $\left[0, \frac{1}{\theta} \left(1 - \frac{n(\beta - 1)}{(n - 1)}\right)\right]$ .*

The proof is relegated to Appendix B. With the aide of this lemma, we are able to identify which interior strategy  $\phi^*$  can or cannot be patched with the corner strategy  $\phi = 1$ , *when that interior strategy hits the boundary line*  $c = 1$ . However, note that the range indicated by Lemma 1 is valid only when  $\beta < (2n - 1)/n$ ; otherwise, the extreme right end of that interval,  $\frac{1}{\theta} \left(1 - \frac{n(\beta - 1)}{(n - 1)}\right)$ , is *negative*. Making use of this result, we can easily see that condition  $\beta < (2n - 1)/n$  is not satisfied in all figures except for Fig.6. As a result, the corner solution  $\phi = 1$  is ruled out and hence the patched solution is not possible in those figures. On the other hand, it follows from (6) that as long as  $\lim_{S \rightarrow 0} V'(S) > -\infty$ ,

$$c(S)|_{S=0} = \frac{\frac{2n - 1}{n}}{\beta + \lim_{S \rightarrow 0} [V'(S) S]} \leq 1 \text{ if and only if } \beta \geq \frac{2n - 1}{n}. \quad (23)$$

Since it is seen that condition  $(2n - 1)/n \leq \beta$  holds in all figures except for Fig.6,  $c(0) \leq 1$  as long as  $\lim_{S \rightarrow 0} V'(S) > -\infty$ .

The second requirement is that the strategies should be **continuous** over the entire range of a state variable, i.e.,  $S \in [0, 1/\theta]$ . More specifically, when the strategies cross the non-invertible curve  $C_2$ , they cease to be continuous at that crossing point, and thus such strategies should be eliminated as an equilibrium solution. For this reason, the strategies  $\phi_2$  in Fig. 2 are once again disqualified as MPE ones.

The third requirement is that the solution should satisfy the transversality condition (or equivalently, the boundedness of the value function). This condition is clearly met for the candidate strategies because they ultimately reach zero social capital stock together with the specification of the objective function (1). In this view, although it appears that the families of the strategy  $\phi_1$  are MPE ones in Fig. 2, they are **not**. The reason is as follows. When the optimal strategy  $\phi_1$  reaches the satiated locus  $1/\theta$ , it has to stay at that hitting point on that locus by freely disposing of the extra resource which has not been consumed, because further social capital accumulation more than  $S = 1/\theta$  is to reduce individual's utility. However, this is a **suboptimal** choice for every individual because the individuals can augment their utility by increasing their consumption levels rather than disposing of that extra resource. Such a choice causes their consumption levels to immediately jump to the steady state consumption level, i.e.,  $c = 1 - (\delta/n)$ . Unfortunately, such a jumping solution entails discontinuity at that point thus violating the second requirement. Alternatively, we may say that the strategy  $\phi_1$  is no longer qualified as the MPE strategy, because each individual who adopts the strategy  $\phi_1$  has an incentive of deviating from this strategy. Taken together, we can conclude that the families of the strategies  $\phi_1$  as well as  $\phi_2$  are **not** equilibrium strategies in Fig. 2. The same argument applies to the strategies  $\phi_1$  as well as  $\phi_2$  appearing in other figures.

In spite of these requirements, there may still be multiple solution curves because there may be a continuum of the interior strategies located *slightly above* the strategy  $\phi^*$  can reach the vertical axis *without touching or crossing the curve  $C_2$  as well as the budget constraint  $c = 1$  during the transition* in Figs. 2, 3 and 8. In contrast, there are cases which do not allow for the existence of any MPE solution at all as illustrated in Figs. 4, 6 and 7, because the curve  $C_2$  prevents any interior strategy from reaching the vertical axis.

Taken together, the results are summarized as follows:

**Proposition 5** *Consider the differential game  $\Gamma(Z_0, 0)$  and assume  $\lim_{S \rightarrow 0} V'(S) > -\infty$ :*

Either if  $\beta \geq \max \left\{ \frac{(n-\delta)(2n-1)-n}{n(n-1)}, \frac{n}{n-\delta}, \frac{2n-1}{n} \right\}$  or if  $\frac{n}{n-\delta} \geq \beta \geq \max \left\{ \frac{(n-\delta)(2n-1)-n}{n(n-1)}, \frac{2n-1}{n} \right\}$  then there may exist a multiple (a continuum) of MPE strategies. The solution paths corresponding to those MPE strategies lead a social capital stock to decrease to nil, while the associated consumption levels monotonically rise through time.

As to Proposition 1, there are several remarks in order. First, Proposition 1 implies that there may be multiple MPE strategies unless “the non-invertibility locus”  $C_2$  prevents the solution path from reaching the vertical axis. More precisely, if “the non-invertibility locus”  $C_2$  crosses not only the vertical axis above the boundary line  $c = 1$  but also the satiated locus  $S = 1/\theta$  below the steady state line, there is no MPE strategy such as in Figs. 4, 6 and 7. The potential existence of multiple MPE solutions would be consistent with the results of Itaya and Shimomura (1993), and Rubio and Casino (2002) which provides multiplicity of equilibrium strategies as well as the uncountable many long run equilibria associated with those multiple nonlinear MPE strategies. This similarity stems from the *boundedness* of the entire space of a state variable imposed by the satiated level of social capital.

Second, the optimal consumption paths associated with those MPE strategies all display a downward sloping in the level of social capital stock. This property evidently reflects the fact that larger stocks of social capital tend to deter excessive consumption which is induced by status-seeking preferences coupled with status-seeking competition in our setting.

Third, most impotently, all figures indicate that any consumption level supported by the MPE strategy (except for the consumption level at the steady state) is always greater than the steady state one, so that the accumulation of social capital *never* takes place, irrespective of the size of an initial social capital stock. In other words, all of the MPE strategies *always* lead the social capital stock to decline to nil; consequently, either if there were initially a small amount of social capital stock in social capital-poor societies or if there were initially a sizable amount of social capital in social capital-rich societies but it is less than the satiated level ( $= 1/\theta$ ), overconsumption driven by status-seeking preferences enhanced by its competition inevitably prevails, so that it eventually vanishes in the long run. As a consequence, the society by itself is unable to escape from a social capital-poverty trap. We may also say that such social capital-poor societies are captured in a poverty trap when status-seeking

preferences are present. The reason is simply that those negative externalities are strong enough to outweigh the positive externality arising from social capital accumulation.<sup>9</sup>

In such a situation, government intervention would be called upon to help the societies escape from such a poverty trap. Since the society by itself can never spontaneously and autonomously accumulate social capital, governments and/or outside authorities have to enforce or regulate the members of the society to accumulate more social capital up to the satiated level by curtailing individual consumption. Put differently, in the societies where status-seeking preferences are commonly observed, the government must play a very active role in a way that corrects or regulates the behavior of rational and forward-looking individuals to large extent so as to curtail their consumption levels thereby leading to the satiated steady state level. Alternatively, the government may implement “a capital big push” in a way of immediately building up the satiated level instantaneously or initially before social capital starts accumulating.

Fourth, the main cause for the above-mentioned “Tragedy of the Commons” is that the incentive to accumulate social capital is too weak. To induce individuals to accumulate more social capital, we need to introduce individual’s pleasure or peculiar benefits from social capital in addition to simply restraining overconsumption caused by the presence of social-status preferences in conjunction with social-status competition. This may correspond to the warm-glow motivation in the model of voluntary provision of public goods (see, e.g., Andreoni, 1990) which also enhances an incentive of donors to supply public goods. We extend the present model to include some sort of peculiar benefits from social capital stock in Section 3.

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<sup>9</sup>Social capital poverty trap also has been captured by Chou (2006) in the endogenous growth model with the Romer (1990)’s R&D function augmented with social capital spillover. He shows that if the spillover effect on one person’s decision to accumulate social capital varies with the level of social capital in the community, such an economy has two possible steady states: one of which is a stable social capital-poor equilibrium and the other of which is an unstable social capital-rich equilibrium and calls the first equilibrium a social capital poverty trap. However, the emergence of a poverty trap stems from a non-concave reduced-form function of social capital which implicitly embodies the social capital spillover. In contrast, our model has microeconomic foundations which explain how the spillover effect of social capital operate across individuals.

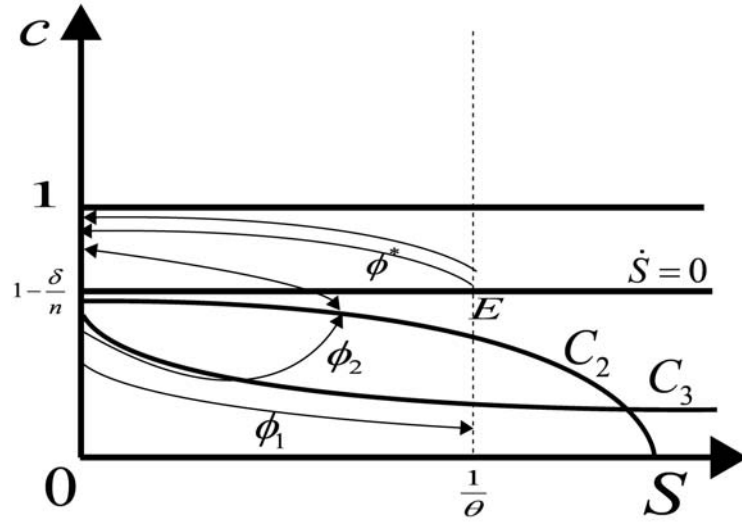


Figure 2:  $\beta \geq \frac{2n}{n-\delta}$

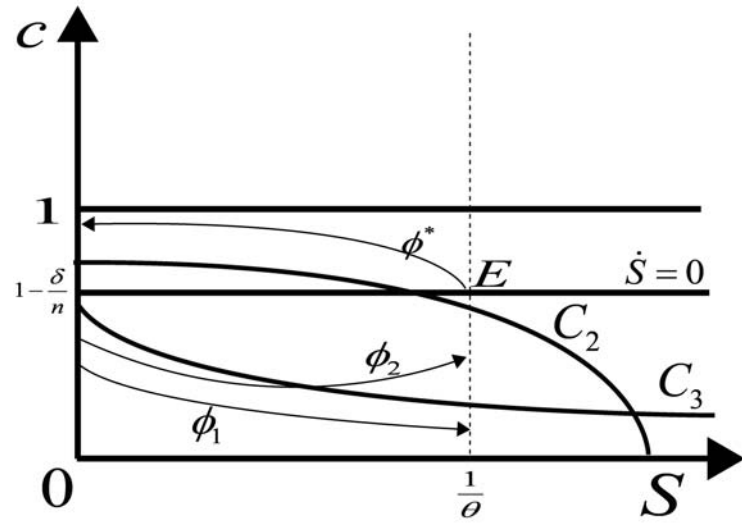


Figure 3:  $\frac{2n}{n-\delta} \geq \beta \geq \max \left\{ \frac{2n-1}{n-\delta}, \frac{(n-\delta)(2n-1)-n}{n(n-1)} \right\}$



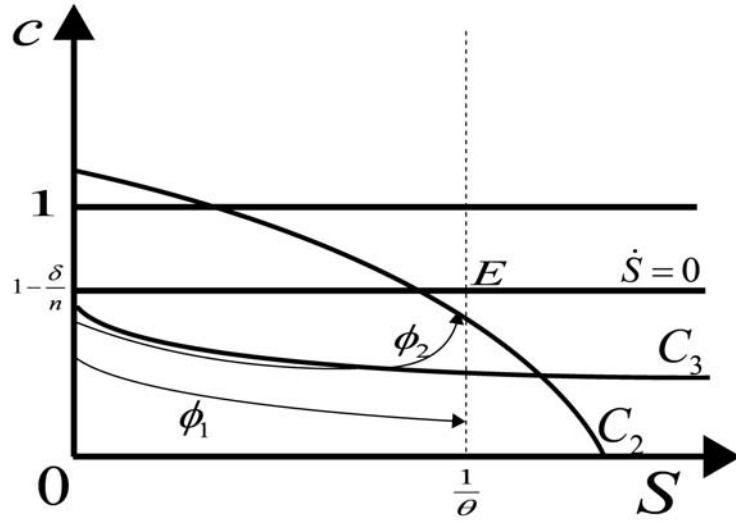


Figure 4:  $\frac{(n-\delta)(2n-1)-n}{n(n-1)} \geq \beta \geq \frac{2n-1}{n-\delta}$

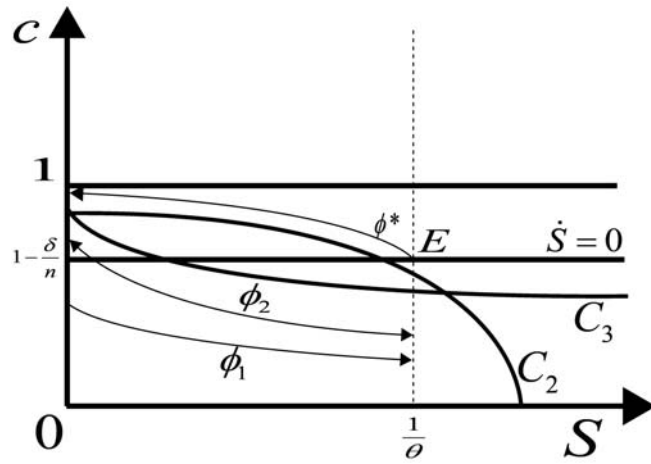


Figure 5:  $\frac{2n-1}{n-\delta} \geq \beta \geq \max \left\{ \frac{(n-\delta)(2n-1)-n}{n(n-1)}, \frac{2n-1}{n}, \frac{n}{n-\delta} \right\}$

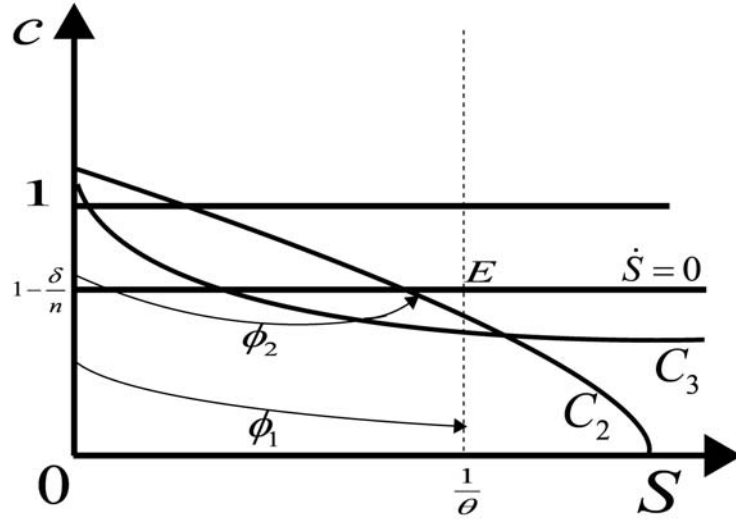


Figure 6:  $\min \left\{ \frac{2n-1}{n}, \frac{(n-\delta)(2n-1)-n}{n(n-1)} \right\} \geq \beta \geq \frac{n}{n-\delta}$

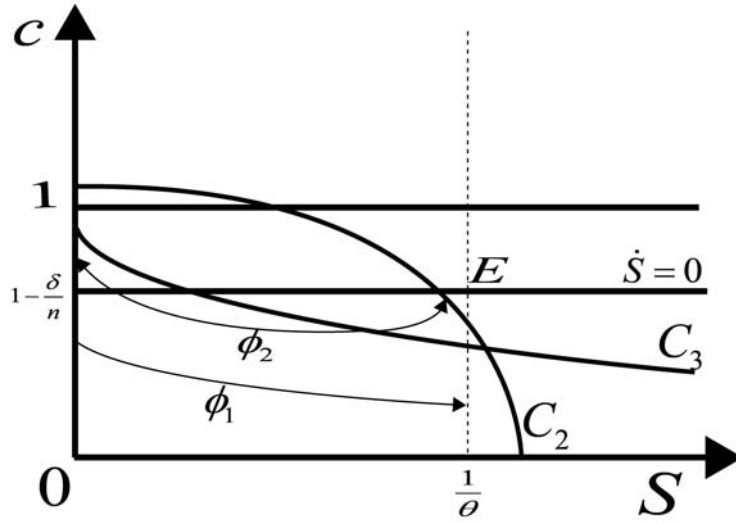


Figure 7:  $\frac{(n-\delta)(2n-1)-n}{n(n-1)} \geq \beta \geq \max \left\{ \frac{2n-1}{n}, \frac{n}{n-\delta} \right\}$

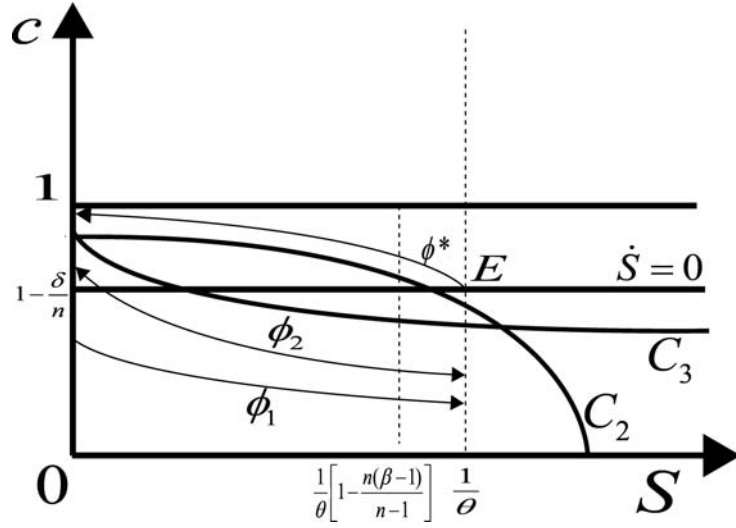


Figure 8:  $\frac{n}{n-\delta} \geq \beta \geq \max \left\{ \frac{2n-1}{n}, \frac{(n-\delta)(2n-1)-n}{n(n-1)} \right\}$

### 3 Peculiar Benefits from Social Capital

In this section, we incorporate the benefit from social capital, which enhances the incentive of individuals to accumulate social capital. To do this, we modify the intertemporal utility function such as:

$$u_i = \int_0^\infty \left[ \log c_i - \beta l_i + \gamma S + (1 - \theta_i(S)) \log \left( \frac{c_i}{\bar{c}} \right) \right] e^{-\rho t} dt, \quad \rho > 0, \quad i = 1, 2, \dots, n, \quad (24)$$

where the parameter  $\gamma$  represents the strength of preferences towards social capital, while the rest of the model is the same as before. The presence of social capital in the utility function may be viewed as the quality of social environment which depends on accumulated social capital (see, e.g., Antoci, et al., 2014).<sup>10</sup> The function, after substitution of  $l_i = c_i$  in (24), the Hamilton-Jacobi-Bellman (HJB) equation is rewritten as:

$$\rho V_i(S) = \max_{\{c_i\}} \left\{ \log c_i - \beta c_i + \gamma S + (1 - \theta_i(S)) \log \left( \frac{c_i}{C/n} \right) + V_i'(S) [S(\sum_{j=1}^n (1 - c_j)) - \delta S] \right\} \quad (25)$$

for all  $t \geq 0$ . The first-order conditions for  $i$ 's choice of consumption are the same as before.

<sup>10</sup>Alternatively, we may assume that individuals have preferences for socializing. In this formulation, the choice variable of  $a_i$  directly enters the utility function instead of the state variable  $S$ . Although this modification does not alter our results essentially, the analysis becomes extremely complicated.

Substituting these optimal solutions (i.e., as  $\{c_i(S)\}$  for  $i = 1, 2, \dots, n$ ) back into the HJB equation (25) associated with agent  $i$ , together with (7), we obtain

$$\rho V_i(S) = \log c_i(S) - \beta c_i(S) + \gamma S + (1 - \theta_i S) \log \left( \frac{c_i(S)}{C(S)/n} \right) + V_i'(S) [S \sum_{j=1}^n (1 - c_j(S)) - \delta S]. \quad (26)$$

By the use of the envelop theorem and focusing on symmetric equilibria, we can finally obtain

$$c'(S) = -\frac{1}{S} \cdot \frac{\rho \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n-1}{n} \right] + \theta \frac{n-1}{n} S [n(1 - c(S)) - \delta] - \gamma}{\frac{1}{c(S)} [(n - c(S)) - \delta] \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n-1}{n} \right] + (1 - \theta S) \frac{n-1}{n} + \beta [n(1 - c(S)) - \delta]}. \quad (27)$$

In view of (27), it turns out that the curves  $C_1$  and  $C_2$  are the same as before, the only curve  $C_3$  is slightly different from the one in (22). Setting the numerator in (27) equal to zero, we can get a new expression for the curve  $C_3$ :

$$c = \frac{(n - \delta - \rho) \theta \frac{n-1}{n} S + \rho \frac{2n-1}{n} - \gamma}{\rho \beta + \theta (n-1) S}, \quad (28)$$

with

$$\lim_{S \rightarrow 0} c = \frac{\rho \frac{2n-1}{n} - \gamma}{\rho \beta}, \quad \lim_{S \rightarrow \infty} c = (n - \delta - \rho) \frac{1}{n} < 1, \quad \text{and} \quad \lim_{S \rightarrow \frac{-\rho \beta}{\theta(n-1)}} c = \infty.$$

Taken together, it turns out that the curve  $C_3$  is an *orthogonal hyperbolic curve* in the  $(S, c)$  space which approaches the vertical line  $S = \frac{-\rho \beta}{\theta(n-1)}$ . The most important difference is that the curve  $C_3$  crosses the line  $1/\theta$  below the steady state line if  $\beta > \frac{n - (\gamma/\rho)}{n - \delta}$ , because

$$\frac{(n - \delta - \rho) \frac{n-1}{n} + \rho \frac{2n-1}{n} - \gamma}{\rho \beta + (n-1)} - \left( 1 - \frac{\delta}{n} \right) = \frac{1}{n} \frac{\rho [n - (n - \delta) \beta] - \gamma}{\rho \beta + (n-1)} \stackrel{\leq}{\geq} 0$$

if and only if  $\beta \stackrel{\geq}{\leq} \frac{n - (\gamma/\rho)}{n - \delta}$ .

Collecting the arguments discussed so far, we can draw Fig. 9. It follows from the above condition that if  $\frac{n}{n - \delta} \geq \beta \geq \frac{n - (\gamma/\rho)}{n - \delta}$ , the curve  $C_2$  will be located *above* the steady state line at  $S = 1/\theta$ , while the curve  $C_3$  is located *below* the steady state line at  $S = 1/\theta$ , as

illustrated in Fig. 9. As a result, the presence of the peculiar preferences towards social capital shifts the curve  $C_3$  downwards, so that the satiated steady state point  $E$  will end up being in between these two curves at  $S = 1/\theta$ . This feature makes it possible that there is the *unique* optimal consumption path supported by the MPE strategy  $\phi^*$  drawn in Fig. 9. Along this MPE solution curve, social capital can spontaneously and automatically reach the satiated steady state point  $E$ . In particular, it should be stressed that **only when** the degree of disutility (i.e..  $\beta$ ) should take intermediate values such as  $\beta \in \left[ \frac{n}{n-\delta}, \frac{n-(\gamma/\rho)}{n-\delta} \right]$ , there exists the unique optimal consumption path supported by the MPE strategy which converges to the satiated steady state level of consumption; see Fig.9. This feature can be explained as follows: excessively higher values of  $\beta$  induce the individuals to deter consumption which in turn gives rise to overaccumulation of social capital thus preventing from reaching the steady state level of consumption corresponding to point  $E$ ; conversely, excessively lower values of  $\beta$  stimulate individual's consumption too much which in turn gives rise to underaccumulation of social capital thereby leading to zero social capital. Note also that consumption does not change monotonically through time. More precisely, there is an unstable steady state equilibrium in which consumption monotonically rises as social capital declines to zero when the initial stock of social capital is less than  $S^E$ , while consumption falls and then rises to its steady state level as social capital increases to its satiated level when the initial stock of social capital is greater than  $S^E$ . It is important to note not only that there will be multiple MPE strategies that lead social capital to zero, as illustrated in Fig. 9, but also that larger values of  $\gamma$  (i.e., the social capital stock becomes more attractive) or lower values of  $\rho$  allow for a wider range of values of  $\beta$  to satisfy the range of  $\frac{n}{n-\delta} \geq \beta \geq \frac{n-(\gamma/\rho)}{n-\delta}$ , whereby improving the likelihood of the existence of MPE strategies. Lower values of  $\rho$  imply that the individual becomes more patient and thus more cooperative to sustain the unique MPE strategy thereby making it possible to escape from a social capital poverty trap.

## 4 Welfare Comparison

In this section, we first compare between social welfare in a hypothetical planner's economy and in a decentralized economy in which social capital is accumulated through voluntary effort (social activity) made by individuals through time.

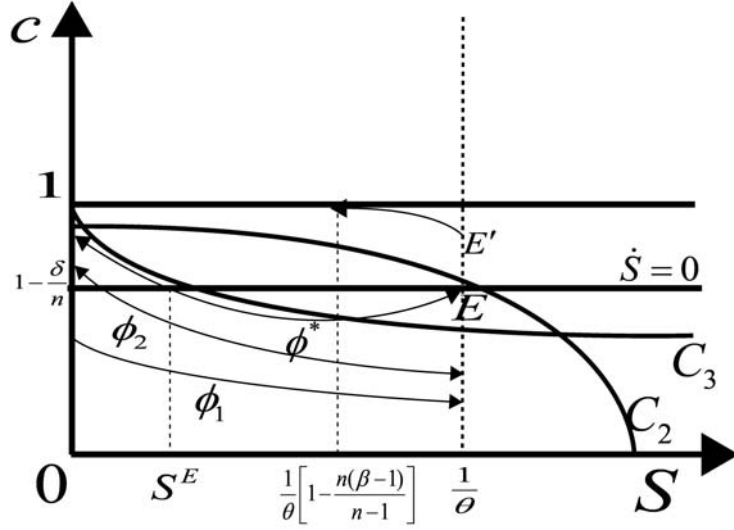


Figure 9:  $\frac{n}{n-\delta} \geq \beta \geq \frac{n-(\gamma/\rho)}{n-\delta}$

First, in the planner's economy, the government is able to attain the first-best resource allocation by directly controlling resource allocations in order to fully internalize a negative externality arising from the aspire for relative consumption. The planner's economy is able to make the efficient use of all the available instruments so as to completely eliminating the externality associated with status-seeking competition and thus restore the first-best allocation. This amounts to maximizing the following utility function over an infinite horizon:

$$u_i = \int_0^{\infty} [\log c_i - \beta l_i] e^{-\rho t} dt, \quad (29)$$

subject to  $c_i = l_i$ , whose optimal solution is given by  $c^P = 1/\beta$ . Note that the the Pareto efficient consumption level is *constant* in the model without peculiar preferences towards social capital.

We compare between the Pareto-efficient level of consumption ( $= 1/\beta$ ) and the consumption level realized in the decentralized economy. To this end, we first consider a case where

$$\frac{1}{\beta} < 1 - \frac{\delta}{n},$$

which can be rewritten as

$$\beta > \frac{n}{n-\delta}.$$

This condition holds true in Figs. 2 – 7. Moreover, Figs. 2 – 7 show that the consumption levels associated with the optimal strategy  $\phi^*$ , including (possibly a continuum of) other optimal strategies, in the decentralized economy are always larger than the Pareto-efficient one ( $= 1/\beta$ ); that is, overconsumption *always* occurs during the transition path as well as in the long-run equilibrium (i.e.,  $S = 0$ ).

Conversely, if the opposite inequality holds; that is,  $\beta < n/(n - \delta)$ , it holds true in Fig. 8 alone. As illustrated in Fig.8, the long-run consumption supported by *the MPE strategy*  $\phi^*$  (i.e.,  $S = 0$ ) in the decentralized economy should be realized within the range of

$$\left[ \frac{\sqrt{1 + 4\beta(n-1)(n-\delta)\frac{2n-1}{n}} - 1}{2\beta(n-1)}, 1 \right],$$

whose extreme left end point is given by the intersection of the non-invertible curve  $C_2$  with the vertical axis; otherwise, *the MPE strategy*  $\phi^*$  will cross or touch the curve  $C_2$ . We compare the minimum level of long-run consumption with the Pareto-efficient one ( $= 1/\beta$ ) thus yielding

$$\frac{\sqrt{1 + 4\beta(n-1)(n-\delta)\frac{2n-1}{n}} - 1}{2\beta(n-1)} - \frac{1}{\beta} > 0 \text{ for } \beta \in \left[ \frac{n^2}{(n-\delta)(2n-1)}, \frac{n}{n-\delta} \right],$$

which reveals that the long run consumption supported by the strategy  $\phi^*$  (including other optimal strategies) in the decentralized economy (i.e.,  $S = 0$ ) is also greater than the Pareto efficient level in Fig.8. Note, however, that when the strategy  $\phi^*$  starts from initial values of  $S$  close to  $1 - (\delta/n)$ , consumption levels of the decentralized economy in earlier stages are clearly less than the Pareto efficient one ( $= 1/\beta$ ).

In the presence of peculiar benefits from social capital the equilibrium path of consumption attained in the decentralized economy is given by (6). In this model the Pareto-efficient level of consumption  $\hat{c}^P$  is characterized by

$$\hat{c}^P = \frac{1}{\beta + \lambda S} < \frac{1}{\beta}, \quad (30)$$

$$\dot{\lambda} - \rho\lambda = -[\gamma + \lambda(n(1-c) - \delta)]. \quad (31)$$

It is clear that the presence of peculiar benefits from social capital, i.e., a positive value of  $\gamma$ , makes the Pareto-efficient consumption level smaller compared to the previous one.

Since social capital is accumulated up to the satiated steady state level in the decentralized economy when  $\frac{n}{n-\delta} \geq \beta \geq \frac{n-(\gamma/\rho)}{n-\delta}$ , the long run consumption level ends up being equal to  $c^{DE} = 1 - (\delta/n)$ , so that it may or may not be greater than the Pareto-efficient consumption level  $\hat{c}^P = 1/(\beta + \lambda S)$ .

To sum up, we have the following lemma:

**Proposition 6** *The long-run consumption level in the decentralized economy is greater than the Pareto-efficient one, while in the presence of peculiar preferences towards social capital the long-run consumption level associated with the unique MPE strategy in the decentralized economy may or may not be larger than the Pareto-efficient one.*

## 5 Concluding Remarks

The first message of this paper is that completely rational behavior inevitably leads to the undesirable social capital poverty trap, because the negative externality arising from status-seeking preferences enhanced by status-seeking competition is large enough to outweigh the positive externality arising from social capital accumulation. In addition, social capital has public good characteristics, so it is likely to be underprovided because of incomplete collective internalization of the positive externality inherent in its formation, which causes an intertemporal free-riding behavior of individuals. As a result, the accumulation of social capital fails to deter inefficiently higher consumption levels which is created by Prisoner's Dilemma situations caused by status-seeking behavior. This result implies not only that repeated social interaction is *not* enough to resolve free-rider problems and deterring opportunism behavior, unlike the literature on repeated games which indicate that it is more likely that cooperation occurs when individuals expect to interact more often in the future, but also that the magnitude of a positive externality generated by social capital accumulation plays a key role in determining whether the game may be either Prisoner's Dilemma games or the Coordination game depending on how much the behavior of coordination accrues more benefits to every individual.

The second message is that to realize higher stocks of social capital we have to enhance the attractiveness of social capital so as to dominate the negative externality arising from status-seeking preferences in conjunction with its competition prevail, because the latter effect is so



strong that it overweighs the positive externality arising from social capital. On the other hand, if the domain is strictly restricted due to the existence of the satiated level of social capital, there may be a continuum of MPE strategies. However, regardless of whether there are multiple or a continuum of MPE strategies, in this case, the result of our paper indicates that in this case it remains the only MPE strategies which lead to zero social capital. From policy perspectives, governments have to construct additional benefits or individual's pleasure towards social capital stock in the presence of status-seeking preferences together with the pressures of status-seeking competition. For example, the accumulation of social capital reduces the crime rates and makes people feel happier arising from the closed connections or strong social ties among individuals.

The model presented in this paper should be developed further in several directions. First of all, since it may not be reasonable to eventually restrict the domain of a state variable due to the existence of a satiated social capital level resulting from a specific functional form of the weight function structured in the utility function (i.e.,  $\theta(S)$ ), the weight function put on status-seeking preferences should be relaxed or possibly extended to allow for a whole domain of  $R_+$ ; for example, *negative* exponential functions. Under this extended setting, it is questionable whether globally defined Markovian perfect equilibrium strategies may or may not exist, because it is highly likely that they will ultimately pass the non-invertible curve. Nevertheless, with help of Rowat's patching method, it might be possible to define globally defined strategies. Secondary, introducing *asymmetric* agents into the present model enables us to compare the results of the present model with those of the static conflict model played by asymmetric agents. Since such an asymmetric-agents model could allow for the emergence of the term representing status-seeking preferences in equilibrium because the ratio between individual consumption and average consumption is not equal to one and thus never vanishes even in equilibrium. As a consequence, it may potentially allow for a variety of MPE strategies and richer outcomes. Another interesting research agenda is to investigate non-Markovian equilibria supported by history-dependent strategies such as trigger ones in the present model, which may also support cooperative subgame perfect equilibria (see Benhabib and Radner, 1992). Fourth, Putnam (2000) has made a distinction between *bridging* social capital in which bonds of connectedness are formed across diverse social groups, and *bonding* social capital that cements only homogenous groups. *Bonding* social capital has positive

effects for the members belonging to this closed groups or networks such as family, closed friends, neighbors and so on, but may have negative effects for society as a whole. *Bridging* social capital making contacts between groups or networks is positive. In this view it is natural to introduce the endogenous choices of individuals on how much time they spend on enhancing closed networks, which contributes to the accumulation of bonding social capital, and to the formation of open networks which contributes to accumulation of bridging social capital.

## Appendix A

Under the assumption of symmetry the first-order condition (6) becomes

$$\frac{1}{c(S)} - \beta + \frac{1}{c(S)} (1 - \theta S) \frac{n-1}{n} - V'(S) S = 0. \quad (\text{A.1})$$

Substituting (A.1) into (10) and further rearrangement yields

$$\begin{aligned} \rho V'(S) &= -\frac{1}{c(S)} (1 - \theta S) \frac{n-1}{n} c'(S) + V''(S) [Sn(1 - c(S)) - \delta S] \\ &\quad + V'(S) [n(1 - c(S)) - S(n-1)c'(S) - \delta], \end{aligned}$$

$$\begin{aligned} [\rho + \delta - n(1 - c(S)) + S(n-1)c'(S)] V'(S) + \frac{c'(S)}{c(S)} (1 - \theta S) \frac{n-1}{n} = \\ V''(S) [Sn(1 - c(S)) - \delta S]. \end{aligned} \quad (\text{A.2})$$

We once again differentiate (6) (i.e.,  $V'_i(S) = \frac{1}{c_i(S)S} \left[ 1 - \beta c_i(S) + (1 - \theta_i S) \frac{\sum_{j=1, j \neq i}^n c_j(S)}{C(S)} \right]$ ) with respect to  $S$  and using  $\sum_{j=1, j \neq i}^n c'_j(S)C(S) - \sum_{j=1, j \neq i}^n c_j(S)C'(S) = 0$  by symmetry, we obtain

$$V''(S) = \frac{1}{c(S)S} \left[ -\beta c'(S) - \theta \frac{n-1}{n} - \left( 1 - \beta c(S) + (1 - \theta S) \frac{n-1}{n} \right) \left( \frac{c'(S)}{c(S)} + S^{-1} \right) \right]. \quad (\text{A.3})$$

Substituting (A.1) and (A.3) into (A.2) yields

$$\begin{aligned}
& [\rho + \delta - n(1 - c(S)) + S(n - 1)c'(S)] \frac{1}{c(S)S} \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n - 1}{n} \right] = \\
& \quad + \frac{c'(S)}{c(S)} (1 - \theta S) \frac{n - 1}{n} = \tag{A.4} \\
& \frac{1}{c(S)S} \left[ -\beta c'(S) - \theta \frac{n - 1}{n} - \left( 1 - \beta c(S) + (1 - \theta S) \frac{n - 1}{n} \right) \left( \frac{c'(S)}{c(S)} + S^{-1} \right) \right] \cdot \\
& \quad [Sn(1 - c(S)) - \delta S].
\end{aligned}$$

Multiplying both sides by  $c(S)S$  and collecting the terms related to  $c'(S)$  on the left-hand side of (A.4) gives

$$\begin{aligned}
& c'(S) \left[ \left( S(n - 1) + \frac{Sn}{c(S)} - Sn - \frac{\delta S}{c(S)} \right) \left( 1 - \beta c(S) + (1 - \theta S) \frac{n - 1}{n} \right) \right. \\
& \quad \left. + S(1 - \theta S) \frac{n - 1}{n} + \beta (Sn(1 - c(S)) - \delta S) \right] = \\
& - [(\rho + \delta - n(1 - c(S))) + S^{-1} (Sn(1 - c(S)) - \delta S)] \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n - 1}{n} \right] \\
& \quad - \theta \frac{n - 1}{n} [Sn(1 - c(S)) - \delta S].
\end{aligned}$$

After rearrangement,, we obtain

$$\begin{aligned}
& c'(S) \left[ \frac{1}{c(S)} ((n - c(S))S - \delta S) \left( 1 - \beta c(S) + (1 - \theta S) \frac{n - 1}{n} \right) \right. \\
& \quad \left. + S(1 - \theta S) \frac{n - 1}{n} + \beta (Sn(1 - c(S)) - \delta S) \right] = \\
& -\rho \left[ 1 - \beta c(S) + (1 - \theta S) \frac{n - 1}{n} \right] - \theta \frac{n - 1}{n} [Sn(1 - c(S)) - \delta S],
\end{aligned}$$

which gives (11).

## Appendix B The proof of Lemma 1

**Proof.** When all individuals play  $\phi = 1$ , the HJB equation (5) becomes

$$\rho V(S) = -\beta + V'(S)(-\delta S). \tag{B.1}$$

Integrating (B.1) yields

$$V(S) = -\frac{\beta}{\rho} + AS^{-\frac{\rho}{\delta}}, \tag{B.2}$$

where  $A$  is an arbitrary constant of integration. It follows from (B.2) that when  $A > 0$ ,  $\lim_{S \rightarrow 0} V(S) = \infty$ . This unbounded limit, together with the fact that  $S(t)$  always converges from any initial value of  $S \in [0, \infty)$  to zero, contradicts the bounded above instantaneous objective function in (1). On the other hand, the first-order condition (6) for the corner solution  $\phi(S) = 1$  together with (B.2) yields

$$1 - \beta + (1 - \theta S) \frac{n-1}{n} > A \left( -\frac{\rho}{\delta} \right) S^{-\frac{\rho}{\delta}}, \quad (\text{B.3})$$

which implies that as  $S \rightarrow 0$ , the right-hand side of (B.3) diverges toward plus infinity when  $A < 0$ . As a result,  $A < 0$  and  $\phi(0) = 1$  are contradictory. Taken together, the only candidate with  $A = 0$  remains as a possible candidate. In this case, the corner strategy  $\phi(S) = 1$  must be consistent with (B.3); consequently,

$$1 - \beta + (1 - \theta S) \frac{n-1}{n} > 0,$$

which can be rewritten as follows:

$$S < \frac{1}{\theta} + \frac{n(1-\beta)}{\theta(n-1)} < \frac{1}{\theta},$$

which completes the proof. ■

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