Sustainable exploitation of a renewable resource: the joint dynamics of the biomass and intergenerational transmission of pro-social values

Ngo Van Long*

McGill University

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Abstract

This paper extends Andreoni's theory of warm glow, by studying the incentives for parents to take collective action to instill a sense of civic pride in their children. I show that the size of the potential gain from increased cooperation plays an important role in the parental incentives to build up pro-social traits in their offspring. A prediction yielded by the model is that communities that expect to gain more from cooperative behaviour tend to invest more in fostering higher levels of cooperation. Applying the idea to the management of a common property resource, I investigate the joint dynamics of the resource stock and of the propensity for pro-social behavior, and find that there is a possibility of multiplicity

*Email: ngo.long@mcgill.ca

of steady states. Steady states with higher resource stocks are associated with higher degrees of pro-socialness. There exists a threshold resource stock level such that if the system starts with an initial resource stock smaller than that threshold, the community will have no interest in cultivating pro-social attitudes.

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1 Introduction

This paper celebrates the 40th anniversary of John Harwick's path-breaking contribution to theory of sustainable development (Hartwick, 1977) as well as the 30th anniversary of James Andreoni's theory of warm-glow giving (Andreoni, 1987, 1988, 1989, 1990). While Hartwick's Rule and the related literature characterizes the investment and extraction decisions that would be compatible with a constant consumption stream, there is little discussion on how agents in a decentralized economy may want to ensure sustainability especially if property rights to resource stocks are not well defined. The risks of overexploitation was well explained by Gordon (1954) and Hardin (1968). Yet, it has been observed that in some communities, common property resources are managed in a sustainable way (Ostrom, 1990). Why do some individuals in some communities refrain from overexploitation even though it would be privately profitable? An obvious reason is that they may feel the *warm glow* from restraining their desire to maximize private material wellbeing at the expense of other members of their community.

It has been well recognized that there is inside each of us a tension between the desire to further one's own material wellbeing and the urge to be socially responsible. This internal tension was highlighted in Arrow's 1974 monograph, *The Limits of Organization*, which opened with the words of a first-century sage, Rabbi Hillel:

> "If I am not for myself, then who is for me? And if I am not for others, then who am I? If not now, when?"

The present paper applies the theory of warm glow to the analysis of sustainable exploitation of common property resources, and extends the warm glow theory in two directions. First, I connect the warm glow with a formulation of a "self-image function" which has as argument the divergence between one's actual action and one's conception of an "ideal action" based on Kantian ethics. The closer one's actual action is to one's ideal action, the better is one's self image.[1] Second, I endogenize the "relative strength" of the self-image function (relative to that of the desire for material wellbeing). I posit that this relative strength, which I call "the propensity for pro-social behavior", depends on one's upbringing during childhood, which in turns depends on the resources (time, effort, and money) spent on moral education. In other words, individuals carry with them their "cultural baggage", which

[1] This formulation is closely related to the model of Brekke et al. (2003), which in turn is related to Akerlof and Kranton (2000).

evolve over time, depending on the mode of production and intergenerational transmission of values.

This view seems to be supported by empirical evidence. A team of anthropologists and economists (Henrich et al. AER, 2001) conducted experimental games in 15 small-scale societies. They found that, even in controlled experiments (one shot game, played anonymously), the subjects used the rules of thumb that serve them well in real life, where they are hunters and gatherers. There was a strong display of cooperative behavior among subjects belonging to the Lamelera tribe (they are whale hunters in eastern Indonesia). In contrast, the Hadza (fruit gatherers in Tanzania) were remarkably uncooperative. In another study, Dell et al. (2017) find that Vietnamese villages differ significantly from each other in terms of collective action and levels of economic development. This was partly due to historical reasons, and partly due to a "virtuous circle". Using data covering a large number of Vietnamese villages, they find a strong correlation between village-level propensity to carry out civic duties and the village prosperity. They offer the following explanation for this correlation: "Villages that are richer might be able to *afford* to invest more in local collective action, creating a virtuous feedback loop that is sustained in the long-run" (p. 25). Our explanation is different: instead of affordability, we emphasize that the size of the potential gains from cooperation depends on the size of the communal resource stock. [2]

Similarly, it has been argued that, compared to citizens of many countries, Canadians are more cooperative, on average, because of Canada's extremely cold winters and drastic snow storms such that (at least in the past) life would be highly precarious without mutual help. Moral education in Quebec's primary schools stresses the importance of civic duties, the acceptance of cultural diversity, the value of solidarity, and the benefits of cooperation. It seems that relative to the "average" Canadian province, in Quebec more resources are devoted to moral education (perhaps at expense of the teaching of numerical skills).

This paper considers an overlapping generation model of a small community whose members are fishers having common access a fishing ground. When an individual is a child, she receives moral education by learning and also by watching how the adults cooperate. Period t children become period $t+1$ adults. Adults exercise fishing efforts. They are torn between the desire to further their own material wellbeing (i.e., harvesting until marginal private

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benefit equals marginal private cost) and the urge to be socially responsible (i.e., harvesting only as much as a Kantian would recommend). Each fisher resolves this tension by maximizing a weighted sum of her personal material wellbeing and her self-image function. The weight that is placed on the self-image function depends on her "degree of pro-socialness", which she takes as given.

We then discuss why parents may have incentives to spend resources to influence their offspring's pro-socialness. Specifically, we focus on the case where the members of the current generation may collectively decide to instill in the future generation a greater sense of pro-socialness than that with which they are endowed. One may figuratively say that parents try to increase the "intensity of the warm glow" that motivates their offspring. Parents know that moral education will encourage their children to engage more readily in tacit as well as explicit social cooperation, and they realize that social cooperation will increase everyone's material wellbeing.

We argue that the size of parental investment in their children's pro-socialness depends on the expected material gain from increased cooperation. Clearly, this expected gain depends on the material base of the economy. In this paper, we use a simple model of common property resource exploitation by members of a village as a metaphor. The size of the biomass (e.g. the stock of fish in a communal fishing ground) determines the magnitude of the expected gain from increased pro-socialness, and thus it has an influence on the incentive for villagers to invest in their offspring's pro-socialness. The model yields a dynamic system that determines the joint evolution of two state variables: the biomass stock and the community's degree of pro-socialness. A prediction yielded by the model is that small communities that are better endowed with natural resource stocks tend to foster higher levels of cooperation. The larger the resource stock, the greater the potential gain from cooperation among the community's members, and this recognition creates a strong incentive for parents to collectively instill a stronger sense of cooperation in their children. This theoretical result is consistent with the empirical finding reported in Dell et al. (2017). We show that the model displays multiple steady states. Interestingly, steady-states with a larger biomass also have a greater steady-state degree of pro-socialness. There is a threshold level of biomass stock below which villagers would have no incentive to invest in moral education. This would in turn leads to the unmitigated tragedy of the commons (Hardin, 1968). If the stock of the biomass exceeds this threshold, incentives exist to invest in moral education, mitigating the tragedy of the commons, consistent with Ostrom (1990) who documented instances of well-managed communal resources.

There is a rich theoretical and empirical literature on how social norms and pro-social behaviors are developed and maintained and on the intergenerational transmission of values (see, for example, Henrich et al., 2001, Dixit, 2009, Giusta, Hashimzade, and Myles, 2017, and Dell et al., 2017)[3]. This literature identifies several pathways of behavioral changes: genetic and evolutionary ones, as well as cultural processes and historical accidents (Bisin and Verdier, 2017; Giuliano and Nunn, 2017).[4] Another pathway is the resource and environmental factor: collective action will emerge where environmental factors are favourable to its emergence (Demsetz, 1967; Wade, 1994). The role of moral education has of course been emphasized by political philosophers. The ancient sage Confucius stated that moral education can be more effective than government regulations: "*Guide them with government orders, regulate them with penalties, and the people will seek to evade the law and be without shame. Guide them with virtue, regulate them with ritual, and they will have a sense of shame and become upright*".[5]

An important implication of our model is that richer countries can help poorer ones by providing them with incentives to invest in pro-socialness. This can be done by taking policy measures to assure them that their communal resources will not be impinged upon by outsiders.

2 Related literature

Andreoni's theory of warm-glow giving (Andreoni, 1988, 1990) has opened up a new field of research, namely the behavioral approach to the explanation of pro-social activites. Brekke et al. (2003) conducted surveys of pro-social behavior in small communities in Norway and found support for the warm-glow theory, which they enrich by adding an explicit self-image function. They suppose that each individual compares her actual level of contribution to a public good and the level that she regards as morally ideal (based on the Kantian reasoning). The closer her actual level is to the ideal level, the higher is her warm flow of self-esteem. In their model, individuals typically do not bring their actual level to their ideal level, because

[3] Henrich et al. (2001) conducted behavioral experiments in 15 small-scaled societies. They report that the whale hunting tribe Lamalera in Indonesia displays a high degree of cooperation while the Hadza hunters and gatherers in Tanzania are uncooperative toward one another.

[4] As an example of the influence of historical accidents, Dell et al. (2017) cited the French colonization of Vietnam in the late 19th century as a contributing factor to the sharp cultural differences between what they call the Dai Viet villages and the (formerly Khmer-owned) regions of South Vietnam, to the South and West of Ho Chi Minh City.

[5] Cites in Bowles (2016, p. 11).

there is a tension between the desire to improve one's self-image and the desire to further one's material wellbeing. A similar kind of tension, between the Kantian self and the Non-Kantian self, is modeled in Alger and Weibull (2013, 2016) where individuals face assortative pairwise matching under incomplete information.

Bénabou and Tirole (2006) provide a theory of pro-social behavior, combining heterogeneity in altruism and greed, on the one hand, with concern for social reputation or self-respect, on the other hand. Like Brekke et al. (2003), Bénabou and Tirole (2006) show that providing rewards or punishment with the aim of encouraging pro-social behavior may have the opposite effect, reducing individuals' contributions. They report empirical evidence that supports this theoretical result. In his recent book, *The Moral Economy*, Samuel Bowles (2016) also emphasizes this "crowding out" problem. He states that the erosion of ethical and other social motivations could be a consequence of policies that economists have favored, such as "the greater use of monetary incentives to guide individual behavior" (p.2).

Pro-social behavior is old as life itself[6]. It is arguable that the Kantian categorical imperative is a fruit of evolution. Natural selection favors societies in which members have developed the habit of, or reverence for, cooperation. Among the primates, humans have a higher propensity to cooperate than other apes (Tomasello, 2014a, 2014b, 2016; de Waal, 1996; Kitcher, 2011). Experimental evidence suggests that chimpanzees and capuchin monkeys also have a well-developed sense of fairness (Proctor et al., 2013; Brosnan and de Waal, 2003), which is very much related to cooperation. In human societies, the propensity for co-operation is a product of evolution that is reinforced by moral education that spreads the "meme"(Dawkins, 1989, p. 192). It is well recognized that tastes and morality are products of evolution (Bala and Long, 2005; Bowles and Gintis, 2011). Along the evolutionary path, norms of behavior are developed. Elster (2017) makes a distinction between moral norms and social norms. While social norms always involve punishment by third parties (Elster, 1999), moral norms need not be associated with external punishment. Several authors have discussed the policy implications of behavioral norms and consumption norms (Dasgupta et al., 2016; Ulph and Ulph, 2017; Buchholz, Falkinger, and Rübbelke, 2014).

Among the first economists to mention the importance of social norms, one should cite Adam Smith (1790), who finds that co-operation and mutual help are incorporated in established rules of behavior, and that

[6]Experiment evidence indicates that non-human primates care about fairness (Proctor et al., 2013, Brosnan and de Waal, 2003). Cooperation exists among chimpanzees and other great apes (de Waal, 1996; Kitcher, 2011).

"*upon the tolerable observance of these duties, depends the very existence of human society, which would* ***crumble into nothing*** *if mankind were not generally impressed with a reverence for those important rules of conduct.*" (Smith, 1790, Part III, Chapter V, p. 190.)

While it is true that for the market mechanism to function efficiently there is no need for the bakers and the grocers to include the welfare of their clients in their utility function, it is also true that the market outcome would be dismal if factories were to dump their toxic waste into waterways and regulators were to look the other way.

Eminent economists such as Smith, Edgeworth, Arrow, Sen have long recognized the importance of morality in economic behavior. Edgeworth (1881, p.104) states that "the concrete nineteenth century man is for the most part an impure egoist, a mixed utilitarian." Harsanyi (1955, p. 316) draws the distinction between a person's 'ethical' preferences and his 'subjective' preferences. Similarly, Arrow (1973), Sen (1977) and Johansen (1976) argue that it can be overly simplistic to suppose that individuals always aim at maximizing a self-regarding utility function regardless of the social context.

Laffont (1975) questions the validity of the Nashian assumption in predicting agents' behavior. To answer the question as to why (at least in some countries) people do not leave their beer cans on the beaches, Laffont's answer is that "Every economic action takes place in the framework of a moral or ethics." According to Laffont, Kantian motivation can explain the pro-social behaviour observed in the beach example and in many other instances of human interactions. Laffont (1975) and Roemer (2010, 2015) propose the concept of Kantian equilibrium in choice situations where all agents are imbued with Kantian ethics. These authors hypothesize that humans constrain their behavior out of moral considerations founded on the Kantian categorical imperative, or on ideas similar to it that are found in most religions and systems of moral philosophy. In game theoretic situations, Kantian behavior has been classified as non-Nash behavior (Cornes and Sandler; 1984). Long (2016, 2017) consider situations where Kantian agents interact with Nashian agents. Grafton, Kompas, and Long (2017) propose the concept of Generalised Kant-Nash equilibrium. Alger and Weibull (2013, 2016) study the evolution of Kantian preferences in a model of assortative matching.

Pro-social behavior has been well documented by experimental economists. According to Bolle and Ockenfeld (1990), moral standards explained observed behaviors better than altruism. Experimental economists have reported that many subjects explain their choice in terms of "wanting to do the right thing" (Dawes and Thaler, 1988; Charness and Dufwenberg, 2006). The experimental/behavioral economics literature tends to explain pro-social outcomes without abandoning Nash behavior: preferences are amended to include in the utility function non-conventional aspects such as altruism, fairness, inequality aversion, reciprocity and so on. (See e.g., Fehr and Schmidt, 1999, Bolton and Ockenfelds, 2000, Charness and Rabin, 2002, Andreoni et al., 2008).

The above literature analyses pro-social behavior within a given population with given characteristics. However, individual preferences or moral attitudes are not static. They are subject to changes. The idea that moral attitudes can be influenced by education is widespread. Researchers in the field of developmental psychology have explored the underlying mechanism. For example, Hoffman (2000) wrote "Peer pressure compels children to realize that other have claims; cognition enables them to understand others' perspectives; emphatic distress and guilt motivate them to take others' claims and perspective into account" (p. 11). Economists have offered models of parental efforts to shape the preferences of their offspring (Bisin and Verdier, 2001; Tabelllini, 2008). The role of moral education has of course been emphasized by political philosophers. The ancient sage Confucius stated that moral education can be more effective than government regulations: "*Guide them with government orders, regulate them with penalties, and the people will seek to evade the law and be without shame. Guide them with virtue, regulate them with ritual, and they will have a sense of shame and become upright*".[7]

3 The role of warm glow in mitigating the tragedy of the commons

Let us begin with a static model of exploitation of a common owned by village consisting of n identical households. Each household consists of an adult fisher, and a child.[8] I assume that the fishers feel a warm glow when they voluntarily restrain from excessive exploitation. Let X denote the size of the biomass, say a stock of fish in a common fishing ground. Let

[7] Cites in Bowles (2016, p. 11).

[8] For simplicity, in order to focus on dynamic aspects, I follow Brekke et al. (2003) and Dixit (2009) and assume that individuals are identical. Static models of voluntary contributions to public goods when individuals are heterogeneous and have imperfect information include Bac and Bag (2003), and Maldonado and Rodrigues-Neto (2016)

E_i denote the fishing effort of agent i, and let

$$E \equiv \sum_{i=1}^{n} E_i, \text{ and } E_{-i} \equiv E - E_i$$

3.1 Assumption on production function and utility function with concern for self-image

Let $Y = F(E, X)$ be the production function, where Y is the number of fish caught. We assume that the function $F(E, X)$ is homogeneous of degree 1 and exhibits positive and diminishing marginal products. The opportunity cost of each unit of effort is γ. The material wellbeing of agent i denoted by π_i, where

$$\pi_i(E_i, E_{-i}, X) \equiv \frac{E_i}{E_i + E_{-i}} F(E_i + E_{-i}, X) - \gamma E_i$$

Following the line of thoughts of Andreoni (1990), I assume that the utility of agent i is a weighted average of her material wellbeing, π_i, and her self-image, s_i, with weights $(1-\theta)$ and θ respectively,

$$u_i = (1-\theta)\pi_i + \theta s_i,\ 0 < \theta < 1$$

where her self-image function is defined as

$$s_i(E_i) \equiv \overline{S} - \max\left\{0, E_i - E_i^K(X)\right\} \tag{1}$$

where $E^K(X)$ is the ideal effort level that a Kantian would recommend, and $\overline{S}$ is some constant. Thus, if the individual's fishing effort is in excess of the ideal effort, she will suffer some loss of self-esteem. The term θs_i is called the *warm glow*.

Following Brekke et al. (2003), let E_i^K denote the fishing effort that would maximize the material wellbeing of the representative fisher, *if all fishers were to choose the same effort level*. This reflects the Kantian categorical imperative.[9]That is, E_i^* is the solution of the

[9]According to Kant, *"there is only one categorical imperative, and it is this: Act only on the maxim by which you can at the same time will that it should become a universal law"* (Kant, 1785; as translated by Hill and Zweig, 2002, p. 222).

problem

$$\max_{E_i} \frac{E_i}{E_i + (n-1)E_i} F(E_i + (n-1)E_i, X) - \gamma E_i$$

It follows that the Kantian effort level, denoted by E_i^K, is the solution of the equation $F_E(nE_i, X) = \gamma$. Since the function $F(E, X)$ is homogeneous of degree 1, it is useful to use the ratio $e \equiv E/X$. Then

$$F(E, X) = XF\left(\frac{E}{X}, \frac{X}{X}\right) \equiv Xf(e)$$

and $F_E(E, X) = f'(e)$. Thus, the ratio of ideal aggregate effort to the stock of biomas, e^K, satisfies the equation

$$f'(e^K) = \gamma \Longrightarrow e^* = f'^{-1}(\gamma)$$

Hence the individual's ideal effort level is

$$E_i^K(X) = \frac{1}{n}e^K X = \frac{1}{n}f'^{-1}(\gamma)X$$

Result 1: *The ideal effort level $E_i^K(X)$ is linear and increasing in the resource stock, X, and is decreasing in the effort cost, γ, and in the population size, n.*

3.2 The Nash equilibrium with warm glow

The utility function of fisher i is a weighted sum of her material well-being and her self-image:

$$u_i = (1-\theta)\left[\frac{E_i}{E_i + E_{-i}}F(E_i + E_{-i}, X) - \gamma E_i\right] + \theta\left[\overline{S} - \max\left\{0, E_i - E_i^K(X)\right\}\right]$$

I assume that each agent adopts Nash behavior to maximize her utility function u_i. Agent i takes E_{-i} as given, and chooses E_i to maximize u_i. This is mathematically equivalent to choosing E to maximize

$$u_i = (1-\theta)\left[\frac{E - E_{-i}}{E}F(E, X) - \gamma\left(E - E_{-i}\right)\right] + \theta\left[\overline{S} - \max\left\{0, E - E_{-i} - E_i^K(X)\right\}\right]$$

or, equivalently,

$$\max_E (1-\theta)\left[\frac{E-E_{-i}}{E}F(E,X)-\gamma\left(E-E_{-i}\right)\right]-\theta\left[E-E_{-i}-E_i^K(X)\right] \tag{2}$$

subject to

$$E-E_{-i}-E_i^K(X)\geq 0 \tag{3}$$

Let $\lambda \geq 0$ be the Kuhn-Tucker multiplier associated with the inequality constraint (3). In a symmetric Nash equilibrium, the equilibrium effort level satisfies the equation

$$(1-\theta)\left[(1-s)\frac{F(E^N,X)}{E^N}+sF_E(E^N,X)-\gamma\right]-\theta+\lambda=0 \tag{4}$$

where $s=\frac{1}{n}$. Clearly, the Nash equilibrium E^N is a function of θ and X. We write

$$E^N=E^N(\theta,X)$$

Consider two polar cases. The first polar case is where $\theta=0$, i.e., each individual cares only about her material well-being. In this case, we obtain the conventional result that at the Nash equilibrium, the marginal cost of effort is equated to a weighted sum of average product and marginal product of E

$$(1-s)\frac{F(E^N(0,X),X)}{E^N(0,X)}+sF_E(E^N(0,X),X)=\gamma \tag{5}$$

Since F is concave in E, the average product is always greater than the marginal product for any positive E. Thus, for any $E>0$,

$$(1-s)\frac{F(E,X)}{E}+sF_E(E,X)>(1-s)F_E(E,X)+sF_E(E,X)=F_E(E,X) \tag{6}$$

It follows that if $\theta=0$, then at the Nash equibrium, the marginal product of effort is lower that its marginal cost, i.e., harvesting is excessive:

$$F_E(E^N(0,X),X) < \gamma \text{ and } E^N(0,X) < E^K(X) \equiv nE_i^K(X)$$

At the second polar case, where $\theta = 1$, the Nash equibrium effort level coincides with the social optimum. The maximization of (2) subject to (3) when $\theta = 1$ yields the FOC

$$-1 + \lambda = 0$$

i.e., $\lambda = 1$ and hence $E^N(1,X) = E^K(X)$.

In the intermediate case where $0 < \theta < 1$, we can characterize the Nash equilibrium effort level E^N by the equation

$$\Psi(E,X,\theta) \equiv (1-\theta)\left\{(1-s)\frac{F(E^N,X)}{E^N} + sF_E(E^N,X) - \gamma\right\} - \theta + \lambda = 0 \tag{7}$$

For concreteness, let us assume that the production function is Cobb-Douglas:

$$F(E,X) = \frac{A}{\alpha}X^{1-\alpha}E^{\alpha} \tag{8}$$

Then

$$F_E = A\left(\frac{X}{E}\right)^{1-\alpha} \text{ and } \frac{F}{E} = \frac{A}{\alpha}\left(\frac{X}{E}\right)^{1-\alpha} = \frac{1}{\alpha}F_E$$

and

$$(1-\theta)\left\{\left[(1-s)\frac{1}{\alpha} + s\right]F_E(E^N(\theta,X),X) - \gamma\right\} - \theta + \lambda = 0$$

It follows that there exists a unique value $\widetilde{\theta} \in (0,1)$ such that when $\theta = \widetilde{\theta}$, we have both $F_E(E^N(\widetilde{\theta},X)) - \gamma = 0$ and $\lambda = 0$, i.e., $E^N(\widetilde{\theta},X) = E^K(X)$. The value $\widetilde{\theta}$ is given by

$$\widetilde{\theta} = \frac{(\beta-1)\gamma}{1+(\beta-1)\gamma} \text{ where } \beta \equiv (1-s)\frac{1}{\alpha} + s > 1 \tag{9}$$

i.e.,

$$\frac{\widetilde{\theta}}{1-\widetilde{\theta}} = (\beta - 1)\gamma$$

For $\theta \in \left(\widetilde{\theta}, 1\right)$, we have $\lambda > 0$ and $E^N(\theta, X) = E^K(X)$, and λ is given by

$$\lambda = \theta - (1-\theta)(\beta - 1)\gamma \text{ for } \theta \in \left(\widetilde{\theta}, 1\right).$$

Result 2: *When $\theta \in \left[0, \widetilde{\theta}\right)$, an increase in the pro-socialness level θ leads to a fall in the excessive effort level*

$$\frac{\partial E^N(\theta, X)}{\partial \theta} < 0 \tag{10}$$

Proof:

For all $\theta \in \left[0, \widetilde{\theta}\right)$, the derivative of $E^N(\theta, X)$ wrt θ is

$$\frac{\partial E^N(\theta, X)}{\partial \theta} = -\frac{\frac{\partial \Psi}{\partial \theta}}{\frac{\partial \Psi}{\partial E}} = \left\{ \frac{\left[(1-s)\frac{F(E^N,X)}{E^N} + sF_E(E^N, X) - \gamma\right] - \left[F_E(E^N, X) - \gamma\right]}{(1-\theta)\left[(1-s)\frac{EF_E - F}{E^2} + sF_{EE}\right] + \theta F_{EE}} \right\} < 0$$

where the numerator is positive in view of (6). Also, for later use, we note that the derivative wrt X is

$$\frac{\partial E^N(\theta, X)}{\partial X} = -\frac{\frac{\partial \Psi}{\partial X}}{\frac{\partial \Psi}{\partial E}} = -\left\{ \frac{(1-\theta)\left[(1-s)\frac{F_X}{E} + sF_{EX}\right] + \theta F_{EX}}{(1-\theta)\left[(1-s)\frac{EF_E - F}{E^2} + sF_{EE}\right] + \theta F_{EE}} \right\} > 0$$

■

Denote by $\widehat{\pi}_i(\theta, X)$ the level of material wellbeing at the symmetric Nash equilibrium:

$$\widehat{\pi}_i(\theta, X) \equiv \frac{1}{n}\left[F(E(\theta, X), X) - \gamma E(\theta, X)\right] \tag{11}$$

Result 3: *For all $\theta \in \left[0, \widetilde{\theta}\right)$, an increase in θ increases the community's level of material wellbeing.*

Proof:

$$\frac{\partial \widehat{\pi}_i(\theta, X)}{\partial \theta} = \frac{1}{n}\frac{\partial \pi_i}{\partial E}\frac{\partial E(\theta, X)}{\partial \theta} = \frac{1}{n}\left[F_E(E^N, X) - \gamma\right]\frac{\partial E^N(\theta, X)}{\partial \theta} > 0 \tag{12}$$

since $F_E(E^N, X) - \gamma < 0$ and $\partial E^N(\theta, X)/\partial\theta < 0$ for all $\theta \in \left[0, \widetilde{\theta}\right)$ ■

Remark: In a dynamic context, term $\frac{\partial \widehat{\pi}_i(\theta_{t+1}, X_{t+1})}{\partial \theta_{t+1}}$ measures the strength of the incentives of the generation t to collectively invest in the pro-socialness of the future generation $t+1$.

4 A dynamic model of the co-evolution of the pro-socialness parameter and the resource stock

We now consider a dynamic model. We model the resource dynamics as in Levhari and Mirman (1980). Following Levhari and Mirman (1980), we assume the biomass evolves according to the equation

$$X_{t+1} = \begin{cases} (X_t - Y_t)^{\omega} \text{ if } X_t > Y_t \\ 0 \text{ otherwise} \end{cases}$$

For tractablility we assume that the function relating aggregate harvest to aggregate effort and the biomass is Cobb-Douglas as specified by (8);

$$Y_t = X_t \frac{A}{\alpha}\left(\frac{E_t}{X_t}\right)^{\alpha} \equiv X_t f(e_t)$$

where

$$f(e_t) \equiv \frac{A}{\alpha} e_t^{\alpha}$$

Then the ideal effort level is

$$E_i^K(X) = \frac{1}{n} X_t \left(\frac{A}{\gamma}\right)^{\frac{1}{1-\alpha}}$$

Each adult agent chooses $E_{i,t}$ to maximize the weighted sum of her material wellbeing and her self-image with weights $(1-\theta_t)$ and θ_t respectively:

$$u_i = (1-\theta_t)\pi_i(E_{it}, E_{-it}, X_t) + \theta_t s_i(E_{it}, X_t) \tag{13}$$

At the symmetric Nash equilibrium, the following condition holds, for all $\theta_t \in \left[0, \widetilde{\theta}\right)$

$$(1-\theta_t)\left\{\beta A \left(\frac{X_t}{E_t}\right)^{1-\alpha} - \gamma\right\} - \theta_t = 0$$

where

$$\beta \equiv (1-s)\frac{1}{\alpha} + s > 1$$

Thus, for all $\theta_t \in \left[0, \widetilde{\theta}\right)$,

$$E^N(\theta_t, X) = X\left[\frac{\beta A}{\gamma + \frac{\theta_t}{1-\theta_t}}\right]^{\frac{1}{1-\alpha}} > E^K(X)$$

because

$$\frac{\beta A}{\gamma + \frac{\theta_t}{1-\theta_t}} > \frac{A}{\gamma} \text{ for all } \theta_t \in \left[0, \widetilde{\theta}\right)$$

The Nash equilibrium aggregate harvest is

$$Y_t = F(E^K(\theta_t, X_t), X_t) = \frac{A}{\alpha}X_t\left[\frac{\beta A}{\gamma + \frac{\theta_t}{1-\theta_t}}\right]^{\frac{\alpha}{1-\alpha}}$$

The equilibrium material well-being of a representative individual in period t is, for all $\theta_t \in \left[0, \widetilde{\theta}\right)$,

$$\widehat{\pi}(\theta_t, X_t) = \frac{F(E(\theta_t, X_t), X_t)}{n} - \gamma\frac{E(\theta_t, X_t)}{n}$$

$$\widehat{\pi}(\theta_t, X_t) = \frac{1}{n}\left\{\frac{A}{\alpha}X_t\left[\frac{\beta A}{\gamma + \frac{\theta_t}{1-\theta_t}}\right]^{\frac{\alpha}{1-\alpha}} - \gamma X_t\left[\frac{\beta A}{\gamma + \frac{\theta_t}{1-\theta_t}}\right]^{\frac{1}{1-\alpha}}\right\}$$

where, for all $\theta_t \in \left[0, \widetilde{\theta}\right)$

$$\frac{\theta_t}{1-\theta_t} < \frac{\widetilde{\theta}}{1-\widetilde{\theta}} = (\beta - 1)\gamma$$

Consider the case where $\alpha = 1/2$. Then

$$\widehat{\pi}(\theta_t, X_t) = \frac{X}{n}\left[\left(\frac{A}{\alpha}\right)(\beta A)\left(\frac{1}{G_t}\right) - \gamma\left(\beta^2 A^2\right)\left(\frac{1}{G_t}\right)^2\right]$$

where

$$G_t \equiv \gamma + \frac{\theta_t}{1-\theta_t} \leq \gamma + (\beta - 1)\gamma = \beta\gamma$$

We can show that $\widehat{\pi}(\theta_t, X_t)$ is increasing in θ_t for all $\theta_t \in \left[0, \widetilde{\theta}\right)$.

4.1 Dynamic evolution of the resource stock under a given θ

In this subsection, we assume that $\theta < \widetilde{\theta}$ and is a constant. Then

$$Y_t = F(E^K(\theta, X_t), X_t) = \frac{A}{\alpha}X_t\left[\frac{\beta A}{\gamma + \frac{\theta}{1-\theta}}\right]^{\frac{\alpha}{1-\alpha}} \leq \frac{A}{\alpha}X_t\left[\frac{\beta A}{\gamma}\right]^{\frac{\alpha}{1-\alpha}}$$

Define

$$D \equiv \frac{1}{\alpha}A^{\frac{1}{1-\alpha}}\beta^{\frac{\alpha}{1-\alpha}} \tag{14}$$

and

$$G(\theta) \equiv \gamma + \frac{\theta}{1-\theta},\ G'(\theta) > 0,\ G\left(\widetilde{\theta}\right) = \beta\gamma, G(0) = \gamma$$

Assume that

$$\frac{D}{G(\theta)} < 1 \tag{15}$$

Then the resource dynamics becomes

$$X_{t+1} = X_t^{\omega}\left(1 - \frac{D}{G(\theta)}\right)^{\omega} \tag{16}$$

Assume $\theta_t = \overline{\theta} < \widetilde{\theta}$. Then equation (16) gives rise to unique interior steady state $X_\infty > 0$

$$X_\infty\left(\overline{\theta}\right) = \left(1 - \frac{D}{G\left(\overline{\theta}\right)}\right)^{\omega/(1-\omega)} \tag{17}$$

Notice that X_∞ is increasing in $\overline{\theta}$.

Proposition 2: *The greater is the pro-socialness parameter $\overline{\theta}$, the larger is the steady-state stock of the resource. As $\overline{\theta}$ tends to $\widetilde{\theta}$, the steady state stock tends to*

$$X_\infty = \left(1 - \frac{D}{G\left(\overline{\theta}\right)}\right)^{\omega/(1-\omega)}.$$

Proposition 3: *The greater is $\overline{\theta}$, the larger is the steady-state material well-being.*

4.2 Parental incentive to invest in moral education of their offspring

Now let us consider moral education. Consider any two adjacent periods, t and $t+1$. We assume that a period t adult's degree of pro-socialness θ_t is completely determined by the moral education that she received in her childhood (in period $t-1$). Adult fishers in period $t+1$ are children in period t , and their own degrees of morality depends on the extent of public provision of moral education in period t.

We assume that in period t, the (identical) adult fishers, taking their own θ_t as given, make two decisions consecutively. First, they each chooses their own fishing effort E_{it}, taking as given E_{-it} and X_t, to maximize the utility $(1-\theta_t)\pi(E_{it}, E_{-it}, X_t) + \theta_t s(E_{it}, X_t)$.Their second decision is a collective one: they collectively decide on the fraction of the aggregate output to be invested in public education in order to influence the degree of pro-socialness of the future generation, θ_{t+1}. Their incentive to increase θ_{t+1} relative to θ_t comes from the realization that their children, when they grow up, would gain from increased cooperation among themselves.

Assume that in their collective decision on education, parents maximize the future generation's utility net of the costs of providing the education.

4.3 The cost of building up pro-socialness

We assume that by spending on moral education of children born in period t, a community can make them become better adults, with a higher θ_{t+1}. as assumed in Dixit (2009). Parents are interested in increasing their children's potential welfare $u_i(\theta_{t+1}, X_{t+1})$ when they become adults. Parents know if all the adult members of the future generation have a greater sense of social responsibilty θ_{t+1}, that will increase their potential welfare $u_i(\theta_{t+1}, X_{t+1})$. Parents make a collective decision by voting on the public provision of moral education, financed by an income tax. (Voting to determine the provision of public good is an idea that was supported in Milton Friedman's book, Free to Choose). Assume that if there is no such moral education, parents with θ_t will be able to pass on to their children only $\mu\theta_t$, where $0 < \mu < 1$.

Since in our model, all parents have the same income, there is no conflict among voters: they will vote for the same tax rate. The cost of increasing θ_{t+1} by any amount $\varepsilon \geq 0$ is born by equally by all the voters in period t. We assume that parents collectively choose a lumpsum tax T_t to finance the education that aims at fostering the meme of moral responsibility in the younger generation.

In choosing T_t, they must balance the cost of moral education (measured in terms of the numeraire good) with its benefits. The cost is amount to current consumption that must be foregone by spending resources on education.

Let T_t denote the cost of increasing the next generation's awareness of social responsibilty, θ_{t+1}, relative to the inherited sense of morality, $\mu\theta_t$, by an amount $\varepsilon_t \geq 0$ (where we assume that $0 < \mu < 1$). Since $0 \leq \theta \leq 1$, we assume

$$\theta_{t+1} = \min\{\mu\theta_t + \varepsilon_t, 1\}$$

The cost of achieving a given $\varepsilon_t \geq 0$ is assumed to be $T_t = T(\varepsilon_t, \theta_t)$. For simplicity, assume the cost function is quadratic in ε_t, with a coefficient that depends on the parents' degree of morality, θ_t, and on the population size, n. However, since n is treated as constant, in what follows we will write σ and $K(\theta_t)$ instead of $\sigma(n)$ and $K(\theta_t; n)$. Then

$$T(\varepsilon_t, \theta_t) = \frac{\sigma}{2}\varepsilon_t^2 + K(\theta_t)\varepsilon_t \text{ where } K(\theta_t) > 0$$

Here σ is a positive parameter.

As far as parental altruism is concerned, we assume that each adult cares only about the potential utility her immediate offspring, and not that of her grand child. Let $\beta < 1$ denote the parental degree of altruism. Note that each adult pays only a fraction $1/n$ of the community's cost $T(\varepsilon_t, \theta_t)$. The adults vote on an education target $\varepsilon_t \geq 0$ to maximize

$$\max \beta u_{i,t+1}(\mu\theta_t + \varepsilon_t, X_{t+1}) - \frac{T(\varepsilon_t, \theta_t)}{n}$$

The FOC for an interior maximum is

$$-\frac{1}{n}\frac{\partial T}{\partial \varepsilon_t} + \beta \frac{\partial u_{i,t+1}}{\partial \varepsilon_t} \leq 0, \ (= 0 \text{ if } \varepsilon_t > 0) \tag{18}$$

We can show that if $K(\theta_t) > 0$ and the resource stock X_{t+1} is small then ε_t^* is zero. The intuition is simple: if the resource stock is small, the gain for cooperation will be small, consequently there is **not enough** incentive for the parent generation to invest in the moral education of their children. Optimal investment is zero in that case.

Proposition 4

(i) *If the vertical intercept of marginal education cost curve is strictly positive (i.e.* $K(\theta_t) > 0$*), then when the community's stock of renewable resource is small, parents have no incentive to instill in their children a sense of social responsibility. They choose* $\varepsilon_t = 0$.

(ii) *If the marginal education cost* $K(\theta_t)$ *is zero at* $\varepsilon = 0$ *, then parents always have no incentive to instill in their children a sense of social responsibility. They choose* $\varepsilon_t^* > 0$.

To analyse the system of difference equations, we construct a phase diagram with θ_t measured along the horizontal axis and X_t along the verical axis. We pay particular attention to the box $[0, 1] \times [0, 1]$ because θ_t is restricted to the interarval $[0, 1]$ and any steady state resource stock must be in $[0, 1]$,

Let us investigate the shape of the curve $\Delta X_t = 0$. The curve representing $\Delta X_t = 0$ is strictly concave in θ if $\omega < 1/2$, strictly convex in θ if $\omega < 1/2$, and linear in θ if $\omega = 1/2$.

Next, we investgate the shape of the curve $\Delta\theta_t = 0$. This curve is neither concave nor convex. Figure 1 illustrates the case where $\omega = 1/2$, $K(0) > 0$. The curve $\Delta X_t = 0$ and the curve $\Delta\theta_t = 0$ intersect each other at four interior points, denoted by P_I, P_L, P_M and P_H .The interior steady-state equilibrium points P_L and P_H are locally asymptotically stable, while the interior steady-state points P_I and P_M are unstable (in the saddlepoint sense).

Proposition 5 (multiplicity of steady states)

Assume $K(0) > 0$. Then the dynamical system may have multiple interior steady states. There exists a threshold resource stock level X_I such that if the system starts at an initial resource stock smaller than X_I, the community will have no interest in cultivating the sense of cooperation.

5 Concluding remarks

This paper investigates the relationship between a community's renewable resource stock and the incentives for parents to take collective action to instill pro-social values in their children. We found that that the size of a community's natural resource stock plays a prominant role in the parental incentives to build up pro-social traits in their offspring. A prediction yielded by the model is that small communities that are better endowed with natural resource stocks tend to foster higher levels of cooperation. The reason is simple: the larger the resource stock, the greater the potential gain from cooperation among the community's members, and this recognition creates the incentive for parents to collectively instill the cooperation spirit in their children. Concerning the joint dynamics of the resource stock and of cultural norms, we found that there may exist a multiplicity of steady states. There exists a threshold resource stock level such that if the system start any initial resource stock smaller than that threshold, the community will have no interest in cultivating the sense of cooperation.

A possible extension of the model is to allow for a richer scope for interactions among players, allowing, for example, for heterogenous individuals and punishments for non-cooperation. The interaction between more cooperative agents and less cooperative agents can potentially explain many social and economic phenomena. For example, Camerer and Fehr (2006) give examples where the existence of strong reciprocators may induce self-regarding players to behave cooperatively. Finally, the model could be extended to allow for dynamic games (see Dockner et al., 2000; Long, 2010).

An important implication of our model is that richer countries can help poorer ones by providing them with incentives to invest in pro-socialness. This can be done by taking policy measures to assure them that their communal resources will not be impinged upon by outsiders.

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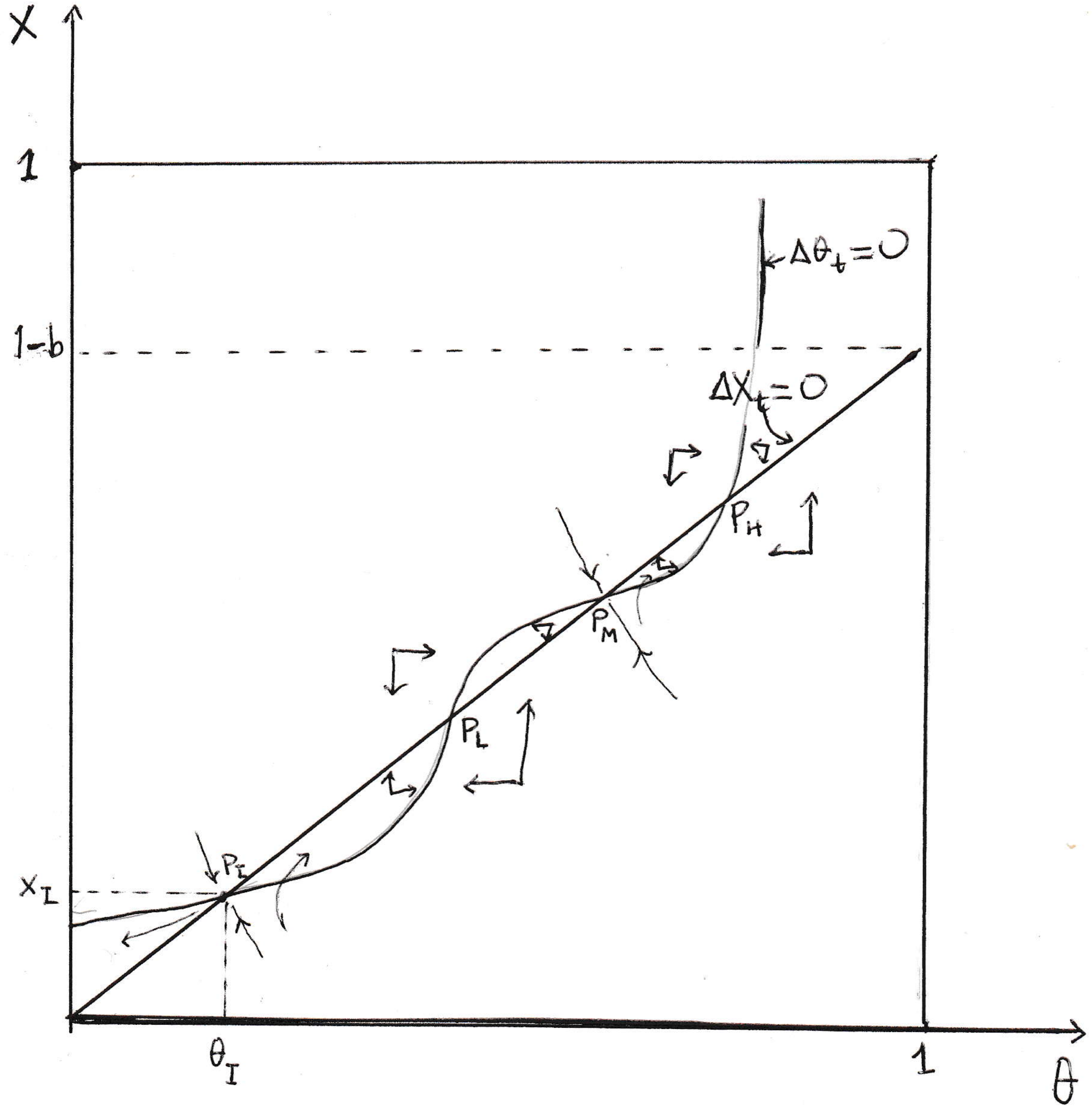

FIGURE 1