Sustainable Fishery With Endogenous Evolution of Fisherfolk's Behavior and Biomass Dynamics.

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Abstract

This paper studies the relationship between a community's renewable resource stock and the incentives for parents to take collective action to instill a sense of Kantian morality in their children. I show 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. I investigate the joint dynamics of the resource stock and of cultural norms, and find that there is a possibility of 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. <filename: Bio_econ_NVL_20170512>

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1 Introduction

It is well known that the "tragedy of the commons" that typically characterizes the exploitation of common property resources can be mitigated, at least in some communities, when agents are guided by social norms that encourage cooperation (Ostrom, 1990). There is a rich theoretical and empirical literature on how social norms and pro-social behaviors are developed and maintained in small communities (see, for example, Henrich et al., 2001, and Dixit, 2009, Dell et al., 2017)[1]. This literature identifies several pathways: genetic and evolutionary ones, as well as cultural processes and historical accidents (Bisin and Verdier, 2017).[2]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 purpose of this paper is to contribute to this literature by focussing on a particular pathway: the relationship between a community's natural resource stock and the incentives for parents to take collective action to instill a sense of Kantian morality in their children. Recall that Kant puts forward the argument that humans, as rational and moral beings, ought to obey the categorical imperative. 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). Or, to put it simply, each ought to act as they want other to act (Cornes and Sandler, 1984, p. 377).

My approach differs from the that of the literature that explains pro-social behavior in terms of altruism (concerns about the sum of the utilities of others), such as Andreoni (1990), Andreoni et al. (2008). Instead of altruism, following the lines of thoughts advanced by Laffont (1975) and Roemer (2010, 2015) and the generalization that I recently proposed (see Long, 2016; Grafton, Kompas, and Long, 2017), I suppose that agents are partially motivated by Kantian ethics, which need not be based on the utility of others. The distinction between altruism and cooperation based on Kantian ethics has been forcefully made in Roemer (2010). He wrote:

We often attempt to instill Kantian ethics in children: "Don't litter- how would

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

[2]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.

you like it if everyonr else littered as you are doing?"...We do not ask individuals to pretend they are less selfish people, in the sense of taking on others' preferences; rather we ask them to evaluate from their own [selfish] viewpoint the consequences of non-cooperative behavior.(Roemer, 2010, p. 18.)

In the models of Laffont (1975), Roemer (2010, 2015), Long (2016), Grafton, Kompas, and Long (2017), the degree of reverence for the Kantian moral norm is taken as given. In the present paper, I attempt to model how the degree of reverence for the Kantian moral norm may change over time, and how the stock of renewable natural resources exploited by the community may influence this evolution. In the present paper, using a simple model of common property fishery resources (as in e.g., Clark and Munro,1975, Levhari and Mirman,1980, Long, 2010; Long and McWhinnie, 2012; see also my survey paper, Long, 2011), I add a cultural element: parents invest in moral education of their children to instill in them a greater sense of cooperation, I show 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. This theoretical result is consistent with the empirical finding in Dell et al. (2017).[3] I investigate the joint dynamics of the resource stock and of cultural norms, and find that there is a possibility of multiplicity of steady states. There exists a threshold resource stock level X_I such that if the system start any initial resource stock smaller than X_I, the community will have no interest in cultivating the sense of cooperation.

2 Related literature

Pro-social behavior is old as life itself[4]. It is arguable that the Kantian categorical imperative is a fruit of evolution. Natural selection favors societies in which members have developed

[3] They offer the following explanation of their 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 the potential gains from cooperation.

[4] Experiment evidence suggests that chimpanzees and monkeys are concerned about fairness (Proctor et al., 2013, Brosnan and de Waal, 2003). Cooperation exists among chimpanzees and other great apes (de Waal, 1996; Kitcher, 2011).

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. 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.

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

> "*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). While the Kant-Nash approach provides a plausible explanation of pro-social behavior, there are alternative explanations. Indeed, there is a literature that explains 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. Contributions to this literature range from theory to experiments, and have offered a wealth of empirical evidence, sometimes with conflicting conclusions about the relative importance of various factors. (See e.g., Fehr and Schmidt, 1999, Bolton and Ockenfelds, 2000, Charness and Rabin, 2002, Andreoni et al., 2008). Despite the difficulty of obtaining conclusive empirical evidence, it would be worthwhile to explore whether the Kantian theory explains the data better than theories that keep the Nash equilibrium approach while modifying preferences to include in the agent's utility function other-regarding factors such as inequality aversion, altruism, and so on.

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; Tabellini, 2008).

3 A model of a fishery where agents are partially motivated by social norms

I consider a community with n families of fishers exploiting a common property fishery. Each adult fisher works for one period (e.g. 25 years), and the next period, she passes on the family business to her offspring. Thus, each adult fisher is labelled with the double index (i,t). Her fishing effort is denoted by E_{it}. The fish biomass in period t is denoted by X_t. The sum of fishing efforts in period t is denoted by E_t. Let

$$E_{-it} = E_t - E_{it}$$

Unlike the models of Levhari and Mirman,1980, Clark and Munro,1975, Levhari and Mirman,1980, Long and McWhinnie, 2012, where static overcrowding externalities are absent, in this paper, I follow the formulation of Dasgupta and Heal (1979, pp. 55-61) and Chichilnisky (1994). I postulate that there is overcrowding externalities in each period, i.e., the average product of effort (i.e., harvest per unit of effort) is decreasing in E_t and increasing in X_t. I denote by $\phi(X_t, E_t)$ the average product function, and assume that average product is decreasing in aggregate fishing effort E_t. The total product function is denoted by $F(E_t, X_t) = E_t\phi(E_t, X_t)$. Assume that $F(E_t, X_t)$ is strictly concave in E_t, and $F(0, X_t) = 0$. The realized harvest of a fisher in period t is denoted by Y_{it}, where

$$Y_{it} = E_{it}\phi(E_t, X_t) = E_{it}\phi(E_{-it} + E_{it}, X_t)$$

The effort cost function is denoted by $C(E_{i_t})$. Assume that $C'(E_{it}) > 0$ and $C''(E_{it}) \geq 0$.

For simplicity, assume that utility function of agent i is linear in Y_{it},

$$U(Y_{it}, E_i) = Y_{it} - C(E_{it}).$$

If agents were completely selfish, each would choose her own effort level, E_{it}, to maximize $E_{it}\phi(E_{-it} + E_{it}, X_t) - C(E_{it})$, taking as given the aggregate effort of other members of the community, E_{-it}. Thus agents do not internalize their overcrowding externalities. The Nash equilibrium of this game is socially inefficient: in any period, it is possible to find some alternative effort profile and a distribution of aggregate output such that everyone is better off.

At the other extreme, let us consider the case where all agents behave according to the Kantian ethics, and fully internalize the overcrwoding externalities. In this polar case, where all agents are "saints", agents act according to following norm:

I hold a norm that says: "If I want to deviate from a contemplated action profile (of my community's members), then I may do so only if I would have all others deviate in like manner." (Roemer, 2015, p. 46.)

Following Roemer (2010), we define the static Kantian equilibrium in period t as a profile of actions $(E_{1t}^*, E_{2t}^*, ..., E_{nt}^*)$ such that each individual finds that if she were to deviate by modifying her E_{it}^* by a factor $\lambda \geq 0$, she would not like the resulting outcome were all others to deviate in like manner. In symbol, $(E_{1t}^*, E_{2t}^*, ..., E_{nt}^*)$ is a static Kantian equilibrium in period t if, for all i, and all $\lambda \geq 0$, we have

$$\lambda E_{it}^* \phi(\lambda E_{-it}^* + \lambda E_{it}^*, X_t) - C(\lambda E_{it}^*) \leq E_{it}^* \phi(E_{-it}^* + E_{it}^*, X_t) - C(E_{it}^*)$$

It can be shown that a static Kantian equilibrium in period t is Pareto efficient for that period. In the context of our fishery model, at a Kantian equilibrium, the marginal product of aggregate effort is equated to each individual's marginal effort cost.

In this paper, I consider the more realistic case where now individuals are neither completely selfish, nor completely saint. I assume they are partly motivated by the payoff they would get if they each maximize their self-regarding utility (taking as given the actions of others), and yet at the same time they feel the urge to 'do the right thing'. They are torn between the two opposing tendencies. What would be a plausible way of modeling their behavior?

To deal with this question, I now take a leaf from the work of Alger and Weibull (2013). In a context of a pair-wise assortative matching model (without natural resources, and no stock dynamics), Alger and Weibull (2013) propose that individuals would choose an action E_i that would maximize a weighted sum of two components: a self-regarding utility $v^S(E_i, E_{-i})$, where E_{-i} is taken as given, and a Kantian component, $v^K(E_i)$ which measures the utility that would obtain if they behave according to the Kantian norm. The weight given to the Kantian component is denoted by θ_i, and is called agent i's degree of morality. If $\theta_i = 1$, we say the individual is pure Kantian. If $\theta = 0$, we say that the individual is a selfish Nashian. If θ_i is somewhere between these two extremes, we say the individual is a partial Kantian.

In this paper, I model fishers as partial Kantians: the representative fisher i in period t would take E_{-it} as given, and choose E_{it} to maximize the weighted sum

$$(1 - \theta_i) v^S(E_{it}, E_{-it}, X_t) + \theta_i v^K(E_{it}, X_t) \quad (1)$$

where θ_i is the weight attached to the Kantian component, $(1 - \theta_i)$ is the weight attached to the selfish Nashian component, and the functions v^S and v^K are defined as follows

$$v^S(E_{it}, E_{-it}, X_t) = E_{it} \phi(E_{-it} + E_{it}, X_t) - C(E_{it}) \quad (2)$$

$$v^K(E_{it}, X_t) = E_{it}\phi((n-1)E_{it} + E_{it}, X_t) - C(E_{it}) \tag{3}$$

That is, in the Kantian component v^K measures the agent's utility supposing that all others were to act like her. Notice that in writing equations (2) and (3) I have assumed that all individuals have the same cost function. This permits us to focus on symmetric equilibrium, where all agents choose the same action in equilibrium if they have the same degree of morality θ_i.

3.1 Analysis of static equilibrium when fishers are partial Kantians

In order to focus on the effect of natural resources on parental incentives to take collective action that would strengthen cooperative behavior of their children, I assume that all fishers have the same degree of morality.

To prepare the ground for our analysis, let us begin with the analysis of a static game of fishery in a community where fishers are partially motivated by ethical concerns. Thus, for the moment, let us abstract from the resource dynamics and consider only one-period optimization. Thus we temporarily drop the subscript t.

Fisher i chooses E_i to maximize

$$(1-\theta)\left\{\frac{E_i}{E_{-i}+E_i}F(E_i+E_{-i}, X) - C(E_i)\right\} +$$
$$\theta\left[\frac{1}{n}F(nE_i, X) - C(E_i)\right]$$

Notice that if $\theta = 0$, agent i chooses her effort level E_i to maximize the term inside the curly brackets, $\{...\}$, taking E_{-i} as given. At the other extreme, if $\theta = 1$, the individual is acting in a pure Kantian manner: Choose the effort level that would maximize her utility if everyone would take the same action. Thus, if $\theta = 1$, the individual's choice of E_i would coincide with the choice that a benevolent social planner would recommend.

The FOC, evaluated at the symmetric equilibrium, is

$$(1-\theta)\left\{\frac{n-1}{n}\frac{F}{E} + \frac{1}{n}F_E - C'(E_i)\right\} + \theta\left[F_E - C'(E_i)\right] = 0$$

Let $E_i(\theta, X)$ denotes the equilibrium individual effort level. If $\theta = 1$, the equilibrium effort, which we denoted by $E_i(1, X)$, is exactly the same as the level that would be chosen by a social planner: the marginal cost of effort is equated to its marginal product,

$$C'(E_i(1, X)) = F_E(nE_i(1, X), X)$$

If $\theta = 0$, the solution denoted by $E_i(0, X)$, exhibits excessive effort: the marginal cost of effort exceeds its marginal product,

$$C'(E_i(0, X)) = F_E(nE_i(0, X), X) + \left(\frac{n-1}{n}\right)\left[\frac{F}{E} - F_E\right]$$

Let us illustrate the result with the following specific functions

$$F(E, X) = \frac{1}{\alpha}AX^{1-\alpha}E^{\alpha} \text{ where } 0 < \alpha < 1$$

$$C(E_i) = \gamma E_i$$

Then

$$\frac{F}{E} = \frac{1}{\alpha}F_E$$

Thus, in a community where all fishers are pure Kantians, the aggregate equilibrium effort level is independent of the number of fishers:

$$nE_i(1, X) = X\left(\frac{A}{\gamma}\right)^{\frac{1}{1-\alpha}} \tag{4}$$

In contrast, if all agents are self-regarding Nashians, the equilibrium aggregate effort level is increasing in the number of fishers:

$$nE_i(0, X) = X\left(\left(\frac{\alpha + n - 1}{n\alpha}\right)\frac{A}{\gamma}\right)^{\frac{1}{1-\alpha}} > E_i(1, X) \tag{5}$$

(It is easy to see that the right-hand side of (5) is increasing in the number of fishers n.)

In the case of partial Kantians, i.e. $0 < \theta < 1$, the aggregate effort is

$$nE_i(\theta, X) = X\left(\left(\frac{(\alpha + n - 1)(1-\theta) + n\alpha\theta}{n\alpha}\right)\frac{A}{\gamma}\right)^{\frac{1}{1-\alpha}}$$

It can be verified that $nE_i(\theta, X)$ is bounded above by Nashian effort and bounded below by the Kantian effort.[5]

The aggregate harvest is

$$\begin{aligned} F(E(\theta), X) &= \frac{1}{\alpha}AX^{1-\alpha}(nE_i(\theta))^{\alpha} = \frac{1}{\alpha}AX\left(\left(\frac{(\alpha + n - 1)(1-\theta) + n\alpha\theta}{n\alpha}\right)\frac{A}{\gamma}\right)^{\frac{\alpha}{1-\alpha}} \\ &= \frac{X}{\alpha}A^{\frac{1}{1-\alpha}}\gamma^{\frac{\alpha}{\alpha-1}}\left(\frac{(\alpha + n - 1)(1-\theta) + n\alpha\theta}{n\alpha}\right)^{\frac{\alpha}{1-\alpha}} \end{aligned} \tag{6}$$

[5] Since $(\alpha+n-1)(1-\theta)+n\alpha\theta < (\alpha+n-1)(1-\theta)+(\alpha+n-1)\theta = (\alpha+n-1)$, we have $nE_i(\theta) < nE_i(0)$. Similarly, since $(\alpha + n - 1)(1 - \theta) + n\alpha\theta > n\alpha(1 - \theta) + n\alpha\theta = n\alpha$, we have $nE_i(\theta) > nE_i(1)$.

Thus an increase in θ will reduce effort and output. Note that $nE_i(\theta) < nE_i(0)$ and $nE_i(\theta) > nE_i(1)$.[6]

Let us compute the equilibrium utility level of the representative adult of the current generation. We obtain

$$W_i(\theta, X) = \frac{F(E(\theta, X), X) - \gamma E(\theta, X)}{n} \tag{7}$$

$$= \frac{1}{n}\left(\frac{A}{n\alpha}\right)^{\frac{1}{1-\alpha}} \gamma^{\frac{\alpha}{\alpha-1}} X Z(\theta)^{\frac{\alpha}{1-\alpha}} (n - Z(\theta)) > 0 \tag{8}$$

where

$$Z(\theta) \equiv (\alpha + n - 1)(1 - \theta) + n\alpha\theta \tag{9}$$

and

$$\frac{dZ}{d\theta} = -(n-1)(1-\alpha) < 0 \tag{10}$$

We can show that equilibrium utility is increasing and concave in the degree of morality, θ :

$$\frac{\partial W_i(\theta, X)}{\partial \theta} > 0, \text{and } \frac{\partial^2 W_i(\theta, X)}{\partial \theta^2} \leq 0 \tag{11}$$

Proposition 1: *In any period, given the resource stock X_t, welfare is increasing in the degree of cooperation, θ.*

3.2 Dynamics of the resource stock under constant social responsibility

In this subsection, we consider the simple case where the community's sense of social responsibility is time-invariant, i.e. θ_t is a equal to a constant $\overline{\theta}$ for all t. We model the resource dynamics as in Levhari and Mirman (1980). Following Levhari and Mirman (1980), we assume the growth function

$$X_{t+1} = (X_t - Y_t)^\omega \text{ where } 0 < \omega < 1, \text{ for } Y_t \leq X_t$$

where, Y_t is the harvest in period t, as given by eq. (6). Define

$$D \equiv \frac{1}{\alpha} A^{\frac{1}{1-\alpha}} \gamma^{\frac{\alpha}{\alpha-1}} \tag{12}$$

Assume that

$$D < \frac{n}{2n-1}$$

[6] Since $(\alpha+n-1)(1-\theta)+n\alpha\theta < (\alpha+n-1)(1-\theta)+(\alpha+n-1)\theta = (\alpha+n-1)$, we have $nE_i(\theta) < nE_i(0)$. Similarly, since $(\alpha + n - 1)(1 - \theta) + n\alpha\theta > n\alpha(1 - \theta) + n\alpha\theta = n\alpha$, we have $nE_i(\theta) > nE_i(1)$.

Then the resource dynamics becomes

$$X_{t+1} = X_t^{\omega} \left(1 - D\left(\frac{Z(\theta)}{n\alpha}\right)^{\frac{\alpha}{1-\alpha}}\right)^{\omega} \tag{13}$$

where, $Z(\theta)$ is given by (9). Since $D < n/(2n-1)$, we have

$$D\left(\frac{Z(\overline{\theta})}{n\alpha}\right)^{\frac{\alpha}{1-\alpha}} < 1$$

Assume $\theta_t = \overline{\theta}$ (constant). Then equation (13) gives rise to unique interior steady state $X_\infty > 0$

$$X_\infty = \left(1 - D\left(\frac{(\alpha+n-1)(1-\overline{\theta}) + n\alpha\,\overline{\theta}}{n\alpha}\right)^{\frac{\alpha}{1-\alpha}}\right)^{\omega/(1-\omega)} \tag{14}$$

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

Proposition 2: *The greater is the community's sense of responsibility $\overline{\theta}$, the larger is the steady state stock of the resource. As $\overline{\theta}$ tends to 1, the steady state stock tends to*

$$(1-D)^{\omega/(1-\omega)}$$

The steady state welfare is, from (14) and (8),

$$W_\infty(\overline{\theta}, X_\infty(\overline{\theta})) = \frac{1}{n}\left(\frac{A}{n\alpha}\right)^{\frac{1}{1-\alpha}} \gamma^{\frac{\alpha}{\alpha-1}} X_\infty(\overline{\theta}) Z(\overline{\theta})^{\frac{\alpha}{1-\alpha}} (n - Z(\overline{\theta}))$$

Using Proposition 2 and the facts that $\frac{\partial W_i(\overline{\theta},X)}{\partial \overline{\theta}} > 0$ and $\frac{\partial W_i(\overline{\theta},X)}{\partial X} > 0$, we can also state

Proposition 3: *The greater is $\overline{\theta}$, the larger is the steady state welfare.*

4 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 an adult's degree of morality θ is completely determined by the moral education that she received in her childhood. 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 function $(1-\theta_t)v^S(E_{it}, E_{-it}, X_t) + \theta_t v^K(E_{it}, X_t)$ as defined by eq. (1). Their next 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 morality 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 care only about the *potential* welfare of their own offsprings, $W_i(\theta_{t+1}, X_{t+1}) = Y^*_{it+1} - C(E^*_{it+1})$, where E^*_{it+1} is the equilibrium effort of the period $t+1$ adults.

To avoid cumbersome notation, **in what follows we set** $\alpha = 1/2$. In period t, each adult can compute her offspring's equilibrium utility for period $t+1$:

$$W_{i,t+1}(\theta_{t+1}, X_{t+1}) = \frac{1}{n}\left(\frac{2A}{n}\right)^2 \gamma^{-1} X_{t+1} Z(\theta_{t+1})(n - Z(\theta_{t+1})) > 0$$

where $Z(\theta_{t+1}) \equiv 1 + (1 - \theta_{t+1})\left(1 - \frac{1}{n}\right) > 1$. It is easy to show that this equilibrium utility is increasing in the sense of social responsibility of generation $n+1$:

$$\frac{\partial W_{i,t+1}(\theta_{t+1}, X_{t+1})}{\partial \theta_{t+1}} = \frac{1}{n}\left(\frac{2A}{n}\right)^2 \gamma^{-1} X_{t+1}(1 - \theta_{t+1})(1 - \alpha)(n-1)^2 > 0 \qquad (15)$$

4.1 The cost of raising children's awareness of social responsibilty

We assume that moral education in period t can make the children have a higher θ_{t+1}, as assumed in Dixit (2009). Parents are interested in increasing their children's potential welfare $W_i(\theta_{t+1}, X_{t+1})$ 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 $W_i(\theta_{t+1}, X_{t+1})$. 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

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

The FOC for an interior maximum is

$$-\frac{1}{n}\frac{\partial T}{\partial \varepsilon_t} + \beta\frac{\partial W_{i,t+1}}{\partial \varepsilon_t} \leq 0, \ (= 0 \text{ if } \varepsilon_t > 0) \tag{16}$$

Then, using (15) and (16), the FOC becomes

$$\beta\left(\frac{2(n-1)A}{n}\right)^2 \gamma^{-1} X_{t+1}(1-\theta_{t+1})(1-\alpha) \leq \sigma\varepsilon_t^* + K(\theta_t)$$

with equality holding if $\varepsilon_t^* > 0$.

Recalling that $\theta_{t+1} = \mu\theta_t + \varepsilon_t$, the above condition may be written as

$$\beta\left(\frac{2(n-1)A}{n}\right)^2 \gamma^{-1} X_{t+1}(1-\mu\theta_t - \varepsilon_t^*)(1-\alpha) \leq \sigma\varepsilon_t^* + K(\theta_t)$$

or

$$\frac{\beta}{\gamma}\left(\frac{2(n-1)A}{n}\right)^2 X_{t+1}(1-\theta_t) - K(\theta_t) \leq \varepsilon_t^* \left\{\sigma + \beta\left(\frac{2(n-1)A}{n}\right)^2 \gamma^{-1} X_{t+1}(1-\mu\theta_t)(1-\alpha)\right\}$$

Thus, if the resource stock X_{t+1} is small, such that $\frac{\beta}{\gamma}\left(\frac{2(n-1)A}{n}\right)^2 X_{t+1}(1-\theta_t) - K(\theta_t) < 0$, 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 marginal education cost* $K(\theta_t)$ *is strictly positive at* $\varepsilon = 0$ *, 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 simplify notation, in what follows, let us write

$$B \equiv \frac{\beta}{\gamma}\left(\frac{2(n-1)A}{n}\right)^2$$

and

$$b \equiv \frac{2A^2(2n-1)}{\gamma n}$$

where we assume that

$$0 < b < 1$$

Now suppose the resource stock is sufficiently large, so that $BX_{t+1}(1-\theta_t) > K(\theta_t)$. Then there exists an positive level of moral education, denoted by $\varepsilon_t^* > 0$. It is given by the equation

$$\varepsilon_t^*(\sigma + BX_{t+1}) = BX_{t+1}(1-\theta_t) - K(\theta_t)$$

Then we have the following first order linear difference equation for θ_t :

$$\Delta\theta_t \equiv \theta_{t+1} - \theta_t = \frac{BX_{t+1}(1-\theta_t) - K(\theta_t)}{BX_{t+1} + \sigma} - (1-\mu)\theta_t \tag{17}$$

Similarly, from eq. (13), we obtain the resource dynamics

$$X_{t+1} = X_t^{\omega}(1 - b(1-\theta_t))^{\omega} \tag{18}$$

which can be written as

$$\Delta X_t \equiv X_{t+1} - X_t = X_t^{\omega}(1 - b(1-\theta_t))^{\omega} - X_t \equiv \psi(X_t, \theta_t) \tag{19}$$

Note that $\psi(X_t, \theta_t)$ is increasing in θ_t. Thus, $\Delta X_t > 0$ to the right of the curve $\psi(X_t, \theta_t) = 0$, see Figure 1.

Substitute eq. (18) into eq. (17), we obtain

$$\Delta\theta_t = \frac{BX_t^{\omega}\left(1-b(1-\theta_t)\right)^{\omega}(1-\theta_t) - (1-\mu)\theta_t\left[BX_t^{\omega}\left(1-b(1-\theta_t)\right)^{\omega}+\sigma\right] - K(\theta_t)}{BX_t^{\omega}\left(1-b(1-\theta_t)\right)^{\omega}+\sigma} \quad (20)$$

In the special case where $\sigma = 0$, Eq. (20) can be simplified as

$$\begin{aligned} \Delta\theta_t &= \frac{B\left(1-b(1-\theta_t)\right)^{\omega}\left[1-(2-\mu)\theta_t\right] - K(\theta_t)X_t^{-\omega}}{B\left(1-b(1-\theta_t)\right)^{\omega}} \\ &\equiv \Omega(X_t, \theta_t) \end{aligned} \quad (21)$$

Note that $\Omega(X_t, \theta_t)$ is increasing in X_t. Thus, $\Delta\theta_t > 0$ above the curve $\Omega(X_t, \theta_t) = 0$, see Figure 1.

To analyse the system of equations (19) and (21), 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 investgate the shape of the curve $\Delta X_t = 0$. This curve is given by the equation

$$X = \left(1-b(1-\theta)\right)^{\frac{\omega}{1-\omega}} \quad (22)$$

Recall that we have assumed that $b < 1$. The right-hand side of (22) is increasing in θ. Along the curve $\Delta X_t = 0$, as $\theta \to 1$, we observe $X \to 1$ and as $\theta \to 0$, we observe $X \to (1-b)^{\omega/(1-\omega)} < 1$. 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 given by the equation

$$BX^{\omega}\left(1-b(1-\theta)\right)^{\omega}\left[1-(2-\mu)\theta\right] = (1-\mu)\sigma\theta + K(\theta)$$

For all $X > 0$, this curve exists only for $1-(2-\mu)\theta > 0$, i.e., for $\theta < 1/(2-\mu)$. Then, provided that $\theta < 1/(2-\mu)$, the curve $\Delta\theta_t = 0$ is represented by pairs (θ, X) that satisfies the equation

$$X = \frac{1}{(1-b(1-\theta))B^{1/\omega}}\left[\frac{K(\theta)}{(1-(2-\mu)\theta)}\right]^{1/\omega} \quad (23)$$

Along this curve, as $\theta \to 0$, we observe $X \to (1-b)^{-1}\left[K(0)/B\right]^{1/\omega} > 0$, and as $\theta \to 1/(2-\mu)$ from the left, we observe $X \to \infty$. 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 (19) - (21) may have multiple interior steady states. There exists a threshold resource stock level X_I such that if the system start any 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 a sense of Kantian morality 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).

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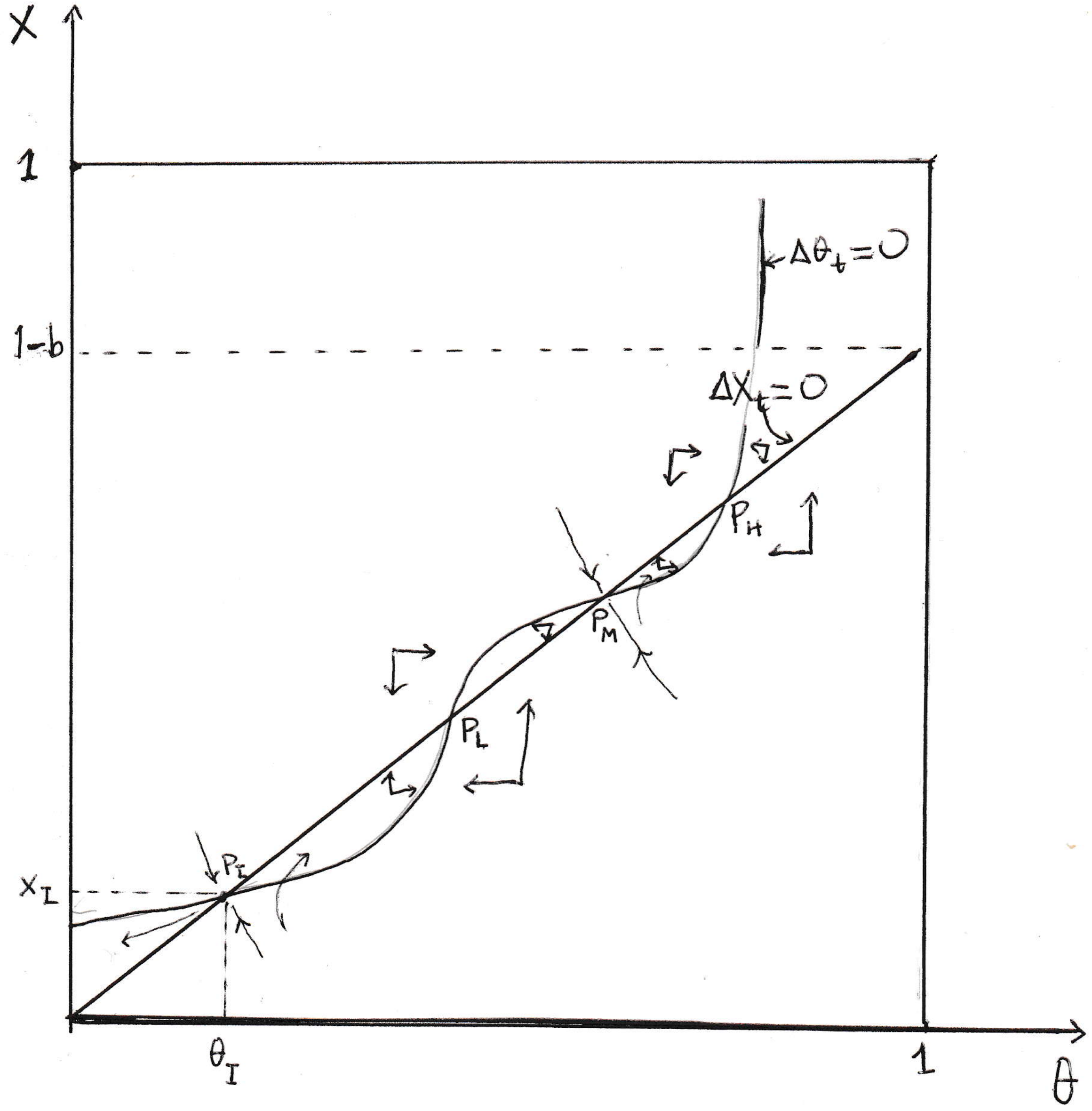

FIGURE 1