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# Status Concern and the Exploitation of Common Pool Renewable Resources*

*Hassan Benchekroun*†, *Ngo Van Long*‡

## Résumé

Nous étudions la possibilité d'aggravation de la tragédie des biens communs quand les joueurs du jeu se soucient de leur statut social. Dans notre modèle les joueurs ont accès à une ressource renouvelable et vendent leurs produits dans un marché commun. Nous nous éloignons de la littérature conventionnelle en considérant la situation dans laquelle chaque joueur se soucie de son statut social. Nous identifions deux canaux qui peuvent avoir un impact sur le bien-être d'un joueur : la récolte et le profit. Avec le premier canal, le niveau d'utilité d'un joueur accroît quand sa récolte est supérieure à la récolte moyenne des autres joueurs. Dans ce cas, nous montrons que ce canal aggrave la tragédie des biens communs. Avec le second canal, le niveau d'utilité d'un joueur accroît quand son profit est supérieur au profit moyen des autres joueurs. Dans ce cas nous prouvons que le souci de son statut social peut temporairement soulager la tragédie des biens communs : le taux d'exploitation devient moins élevé dans un intervalle de la taille des stocks.

**Mots clés** : statut social; performance relative; envie; ressources de propriété commune; oligopolie

## Abstract

We study the possibility of aggravation of the tragedy of the commons when the players of the game care about social status. In our model the players share access to a renewable resource and sell their production in a common market where they are oligopolists. We depart from the mainstream literature on common pool resource oligopolies by considering that each player cares about her social status. We identify two channels that may impact a player's welfare: harvest and profits. Under the first channel, a player has a bump in her utility when her harvest is larger than the average harvest of the rest of the players. In this case we show that the presence of this channel exacerbates the tragedy of the commons. Under the second channel, a player enjoys a bump in her utility if she manages to earn more profits than the average profit of the other players. In this case we show that social status concern may temporarily alleviate the tragedy of the commons: it results in a decrease of extraction over an interval of stock sizes.

**Keywords**: Social Status; Relative Performance; Envy; Common Property Resources; Oligopoly

**Codes JEL/JEL Codes** : D62; Q20; Q50

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# 1 Introduction

The utility that an economic agent derives from her consumption, income, or wealth tends to be affected by how these compare to other economic agents' consumption, income or wealth. This has been established in different contexts. While we label this status concern, some authors label it as envy, or positional externalities, or keeping up with the Joneses[1] (Veblen, 1899; Pollack,1976; Frank, 1985, 1990, 2007). Veblen (1899) emphasizes the pervasiveness of emulation, which he defines as 'the stimulus of an invidious comparison which prompts us to outdo those with whom we are in the habit of classing ourselves.' He claims that 'with the exception of the instinct for self-preservation, the propensity for emulation is probably the strongest and most alert and persistent of economic motives proper.' Emulation can lead to direct contests, and to wasteful use of efforts and other real resources.[2]

The main finding in the context of a common pool resource extraction problem is that status concern tends to exacerbate the tragedy of the commons; i.e., it results in a more aggressive grabbing of the resource, and this leads to lower welfare for all. The importance of the relative performance of an individual compared to the group is not limited to economic environments. The evolutionary biologist Richard Dawkins (1986, p.184) noted:

> Why, for instance, are trees in the forest so tall? The short answer is that all the other trees are tall, so no one tree can afford not to be. It would be overshadowed if it did... But if only they were all shorter, if only there could be some sort of trade-union agreement to lower the recognized height of the canopy in forests, all the trees would benefit. They would be competing with each other in the canopy for exactly the same sun light, but they would all have "paid" much smaller growing costs to get into the canopy.

Because of status concern, private decisions on consumption or asset accumulation generate externalities, and as a result one can no longer presume that a competitive equilibrium is Pareto efficient. A number of papers have studied the effects of status concern on saving behavior, labor supply, public good provision, bequest and inequality (e.g., Fisher and Hof, 2000; Alvarez-Cuadrado et al. 2004; Liu and Turnovsky, 2005; Wendner and Goulder 2008; Alvarez-Cuadrado and Long, 2012; Eckerstorfer and Wendner, 2013). Several authors have studied the effect of status concern on environmental quality (Ng and Wang, 1993; Howarth, 1996, 2000, 2006; Brekke and Howarth, 2002).[3]

In the case of a common pool renewable resource the effect of harvesting on the net rate of renewal of the resource plays an important role in the future availability of the resource. The effect of status concern on resource depletion needs to be examined within the context of a dynamic model that accounts for biological reproduction. Long and McWhinnie (2012) examine this question in a dynamic game with a logistic growth function.[4] They show that status concern results in a lower stock of the resource in the steady state. They

[1] In this paper, these terms could be used interchangeably.

[2] For a recent survey of the theory of contests, see Long (2013).

[3] Brekke and Howarth (2002) use a dynamic model to show that the concern for status may lead agents to underestimate non-market environmental services. Extending the work of Stokey (1998), they show that consumption interdependence exacerbates the rate of environmental degradation.

[4] Alvarez-Cuadrado and Long (2011) examine the impact of envy on resource depletion, but they abstract from strategic behavior. Katayama and Long (2010) investigate the role of status-seeking in a dynamic game with a non-renewable natural resource and physical capital accumulation. Long and Wang (2009) modify the linear-growth model of Tornell and Lane (1999) to account for the impact of status concerns on the rate of resource grabbing.

find that this result is robust to changes in the source of status concern; i.e. whether fishermen are affected by the relative catches or relative profits, status concern leads to a more aggressive depletion of the resource in the long-run. The analysis of Long and McWhinnie (2012) relies on two key assumptions: first, each agent takes as given the time paths of resource exploitation of other agents (i.e., the authors restrict attention to open-loop strategies); and second, the agents take the market price of the extracted resource as given (i.e., the goods markets are perfectly competitive).

In this paper, we relax those assumptions. We model the situation where (a) each agent anticipates that at any point of time in the future, other agents will choose their harvesting levels based on their concurrent observation of the resource stock level[5]; and (b) each agent can influence the market price in each period, by controlling her supply to the market. Our model thus displays three types of externalities. First, there is the well-known common pool externality. Second, there is status externality. Third, the oligopolistic market structure is a form of externality: when one agent increases her output, the market price falls, resulting in lower revenue for other firms.

Why might oligopolists be concerned about their relative output? One reason may be that a firm's relative output is a proxy for its market share. Companies are often ranked in terms of their market share. Another possible reason is that there is a high correlation between a firm's output and its employment level, or the size of its fleet. These can function as status symbols.

We show that when agents use feedback strategies and the transition phase is taken into account, the well established result that status concern exacerbates the tragedy of the commons must be seriously qualified. More specifically, when agents are concerned about their relative profit, we show that there exists an interval of the stock size of the resource for which the extraction policy under status concern is less aggressive than the extraction policy in the absence of status concern. However, it remains true that starting at any common initial stock, the steady-state equilibrium stock reached in a game where agents are concerned with relative status is lower than that reached in a game where they are not. It is well known that when rivalrous agents are heterogeneous (so that there are winners and losers in the race for status), the implications of status concern on welfare depend, among other things, on whether the pleasure derived from outdoing others and the pain suffered by the losers should be accounted for in the measure of social welfare.[6] In this paper, we consider the welfare implication of status concern in the presence of a different source of heterogeneity: there are non-active agents whose welfare matters. In our symmetric oligopoly game, when we take into account the effects of price changes on the consumers surplus, we find that the impact of status concern on social welfare depends on the initial stock of the resource.

The benchmark renewable resource oligopoly model we use has recently been exploited to examine a number of important questions related to dynamic oligopolies and productive assets, such as the role of property rights (Colombo and Labrecciosa, 2013a, 2013b), Bertrand rivalry versus Cournot rivalry (Colombo and Labrecciosa, 2015), the role of nonlinear strategies (Colombo and Labrecciosa, 2015; Lambertini and Montavani, 2014) and the impact of market integration in an international trade framework (Fujiwara, 2011). None of these papers has examined the impact of status concern on the exploitation of the resource.

[5] Technically, this means that we use the concept of Markov perfect equilibrium, as opposed to open-loop equilibrium. See Dockner et al. (2000) or Long (2010) for discussions on the relative merits of these equilibrium concepts.

[6] Rawls (1970, p. 545) wrote "Suppose...that how one is valued by others depends upon one's relative place in the distribution of income and wealth. (...) Thus, not everyone can have the highest status, and to improve one person's position is to lower that of someone else. Social cooperation to increase the conditions of self-respect is impossible. Clearly this situation is a great misfortune."

## 2 Model

Consider a common property resource exploited by $n$ players. Let $c_i(t) \geq 0$ denote player $i$'s output (or harvest) at time $t$. The total harvest at $t$ is

$$C(t) = \sum_{i=1}^{n} c_i(t).$$

The total harvest is sold in the market, and under a linear demand function, the market clearing price is

$$p_i(t) = A - C(t).$$

Player $i$'s marginal cost is a constant, $b_i > 0$, and her profit is

$$\pi_i(t) = [A - C(t)]\, c_i(t) - b_i c_i(t).$$

We assume that $A > b$. Let us define

$$a_i \equiv A - b_i > 0.$$

Then the profit of player $i$ is $(a_i - C)c_i$.

We assume that the utility of each player is the sum of three terms

$$\begin{aligned} u_i \quad &= \quad (a_i - C)\, c_i + \theta\,(c_i - c_{-i}) \\ &\quad\quad +\beta \left( (a_i - C)\, c_i - \frac{\Sigma_{j \neq i}\,(a_j - C)\, c_j}{n-1} \right) \end{aligned}$$

where we define $c_{-i}$ as the average harvest of all other agents:

$$c_{-i} \equiv \frac{1}{n-1} \sum_{j \neq i} c_j = \frac{C - c_i}{n-1}$$

The first term in the utility of each player is the profit from her harvest $c_i$. The second term corresponds to the case of other-regarding preferences where players compare their catch to the average of the other players' catches and the last term captures the fact that each player compares her profits to the average profit of the other players.

The resource stock, denoted by $X$, evolves according to the following differential equation

$$\dot{X} = F\,(X) - \Sigma_i c_i, \;\; X\,(0) = X_0 \tag{1}$$

where, for tractability, we assume that the natural growth function $F(X)$ is 'tent-shaped'[7]

$$F\,(X) = \begin{cases} \delta X & \text{for} \quad X \leq X_y \\ \delta X_y \left( \dfrac{\overline{X} - X}{\overline{X} - X_y} \right) & \text{for} \quad X > X_y. \end{cases} \tag{2}$$

The parameter $\delta > 0$ is called the intrinsic growth rate of the resource. When the resource stock reaches a critical level $X_y$, the growth rate begins to decline. It becomes zero when the stock is at the 'carrying

[7] This formulation was first proposed in Benchekroun (2003), for tractability. This tent-shaped growth function approximates the usual logistic growth function described in standard textbooks, such as Tietenberg and Lewis (2012), Perman et al. (2011), and used in Long and McWhinnie (2012).

capacity level' $\bar{X}$. For stock levels greater than $\bar{X}$, the growth rate is negative. For simplicity, we normalize $\bar{X}$ to 1.

The highest feasible rate of harvest consistent with keeping the resource stock stationary occurs at the stock level $X_y$. We refer to $X_y$ as the 'maximum-sustainable-yield' stock level, and to $\delta X_y$ as the 'maximum sustainable yield' (MSY).

Each player takes as given the exploitation strategies of other players. We assume that agents use feedback strategies, i.e., each agent conditions her action (catch level) on the current stock level, $c_j = \phi^j(X)$.

Since agents are symmetric, we focus on a symmetric equilibrium, $c_i = c_j = \phi(X)$, for all $i, j$. Agent $i$ chooses the time path $c_i$ to maximize the discounted stream of her utility flow:

$$\max_{c_i(.)} \int_0^\infty e^{-rt} u_i(c_i, C) dt$$

where $C = c_i + \sum_{j \neq i} \phi_j(X)$ and $r > 0$ is the discount rate. The maximization is subject to the transition equation, $\dot{X} = F(X) - C$, and the non-negativity constraints $c_i \geq 0$ and $X \geq 0$. The feedback strategies of other players, $c_j(t) = \phi_j(X(t))$, $j \neq i$, imply that player $i$'s profit and utility at any time $t$ indirectly depend on the concurrent stock level.

In what follows, for tractability, we focus on the case where all firms have the same marginal cost, $b_i = b$ for all $i$. Here we are sacrificing realism for the sake of simplicity. Even though in equilibrium all agents will achieve the same status, this does not mean that agents are any less motivated in their desire not to fall behind. As we shall see, the status concern parameters have impacts on the equilibrium exploitation strategy and on the steady-state level of the resource stock.

We solve for a symmetric Markov-perfect Nash Equilibrium extraction strategy and use it to examine the impact of other-regarding preferences on the equilibrium extraction policy.[8] We separately consider the case where agents perceive that relative catch is the signal of status (i.e., $\theta > 0$ and $\beta = 0$) and the case where they perceive that relative profit is the signal (i.e., $\theta = 0$ and $\beta > 0$). We show that the impacts of status signal on the equilibrium extraction policy differ sharply between the two cases. In sharp contrast with the standard result in the literature, we show that for a range of stock levels, status concern with respect to relative profits can result in smaller extraction than in the absence of status concern.

# 3 Relative output as the only signal of status: $\theta \geq 0$ and $\beta = 0$

This section deals with the case where the relative output, $c_i - c_{-i}$, is the only signal of status, i.e. $\theta \geq 0$ and $\beta = 0$. We will focus on the symmetric equilibrium, such that all agents use the same exploitation strategy. When the status concern is based on relative catch, the equilibrium strategy will be denoted by $c = \phi_c(X, \theta)$, where the subscript $c$ refers to catch-based status concern. In the following lemma, we show that the equilibrium strategy has the following properties. First, the exploitation is a continuous, non-decreasing, and piece-wise linear function of the stock. Second, there are two endogenously determined threshold levels of stock, denoted by $X_1(\theta)$ and $X_2(\theta)$, where $0 < X_1(\theta) < X_2(\theta)$, such that

(a) For all $X \in [0, X_1(\theta)]$, all agents refrain from exploitation, allowing the resource stock to grow. They are in fact 'investing' in the resource by waiting. We call $X_1(\theta)$ the '*waiting threshold.*'

[8] For a definition of Markov-perfect Nash equilibrium, see e.g., Dockner et al. (2000).

(b) For all $X \in [X_1(\theta), X_2(\theta)]$, the exploitation is a linear and increasing function of the resource stock. An increase in $\theta$ will shift upward this positively-sloped section of the equilibrium strategy.

(c) For all $X \geq X_2(\theta)$, the agents behave as if the resource stock had no value: beyond the stock level $X_2(\theta)$, they are effectively 'static oligopolists.' We call $X_2(\theta)$ the '*upper threshold*.'

In order to focus on the interesting cases, we make the following assumption.

**Assumption A1:** *The intrinsic growth rate $\delta$ is sufficiently great, such that*

$$\delta > \max\left\{\frac{(1+n^2)r}{2}, \frac{a\left(1+n^2\right)+(n-1)\,n\theta}{X_y\,(1+n)^2}\right\} \tag{3}$$

*and the status-concern parameter $\theta$ is rather low, such that*

$$\theta \leq \frac{a}{n}\left[\frac{2\delta-(1+n^2)r}{2\delta+(n-1)r}\right]. \tag{4}$$

The first part of inequality (3) ensures, in the case where $\theta = 0$**,** that no one has an incentive to drive the resource to extinction ($X_1(0) > 0$), because the intrinsic rate of growth, $\delta$, is sufficiently high relative to the rate of discount. When $\theta > 0$ we also require inequality (4) to ensure that the threshold $X_1(\theta)$ is nonnegative. The second part of the inequality (3) ensures that the 'upper threshold' $X_2(\theta)$ is smaller than the maximum-sustainable-yield stock, $X_y$.

**Lemma 1:** *Under Assumption A1, the following exploitation strategy, adopted by all agents, is a Markov-perfect Nash equilibrium*

$$c = \phi_c(X;\theta) = \begin{cases} 0 & \text{for } X \leq X_1(\theta) \\ (X - X_1(\theta))\,\frac{c_s(\theta)}{X_2(\theta)-X_1(\theta)} & \text{for } X \in [X_1(\theta), X_2(\theta)] \\ c_s(\theta) & \text{for } X \geq X_2(\theta) \end{cases} \tag{5}$$

*where $c_s$ is the output level that the representative oligopolist motivated by relative-output status concern would choose if the game were a static game:*

$$c_s(\theta) = \frac{a+\theta}{1+n}.$$

*The 'waiting threshold' $X_1(\theta)$ is decreasing in $\theta$, and is given by*

$$X_1(\theta) = \frac{a\left(2\delta-\left(1+n^2\right)r\right)-\left(2\delta+(n-1)\,r\right)n\theta}{\delta\,(1+n)^2\,(2\delta-r)} \geq 0.$$

*The 'upper threshold' $X_2(\theta)$ is increasing in $\theta$ and is given by*

$$X_2(\theta) = \frac{a\left(1+n^2\right)+(n-1)\,n\theta}{\delta\,(1+n)^2}.$$

*In particular, the positively-sloped section of the strategy $\phi_c(X;\theta)$ is shifted up uniformly when $\theta$ increases.*

**Proof**: See Appendix A.

**Remark 1:** The equilibrium strategy can also be written as

$$\phi_c(X;\theta) = \min\left\{c_s(\theta), \max\left[0, c_s(\theta)\frac{X-X_1(\theta)}{X_2-X_1(\theta)}\right]\right\}$$

It is straightforward to verify that when the above equilibrium strategy is chosen by $n-1$ agents, the remaining agent will find that her optimal exploitation must also satisfy that strategy. This is the standard approach for establishing that a candidate strategy profile is a Markov-perfect Nash equilibrium. See, e.g., Dockner et al. (2000). In the case where $\theta = 0$, this equilibrium is the same as the one obtained in Benchekroun (2008).

It is interesting to note that although we have identical players and examine a symmetric equilibrium, status concern still affects the equilibrium and its outcome (i.e. the symmetric equilibrium and its corresponding equilibrium value functions depend on the status concern parameter $\theta$). Even though agents know that in equilibrium their performances will be equal, they must work harder when $\theta$ is greater, because each knows that she will be left behind if she does not.

**Discussion**: The equilibrium strategy displays plausible properties. When the resource stock is so large that $X \geq X_2(\theta)$, the agents behave as if the resource stock would not be affected by their exploitation, and we obtain the static Cournot equilibrium output which is increasing in the status concern parameter $\theta$, i.e., $\frac{dc_s}{d\theta} > 0$. When the resource stock is very small, such that $X < X_1(\theta)$, no exploitation will take place, because agents are willing to wait for the stock to grow. Waiting is a form of investment. We find that the waiting threshold $X_1$ becomes smaller as $\theta$ increases:

$$\frac{dX_1}{d\theta} = \frac{-\left(2\delta + (n-1)\, r\right) n}{\delta \left(1+n\right)^2 \left(2\delta - r\right)} < 0.$$

This means that, when the initial stock is below the threshold $X_1(\theta)$**,** an increase in status concern leads agents to stop waiting sooner, a very intuitive result. Everyone tries to grab a piece of the resource before the others start grabbing; but of course in equilibrium they start their grabbing at the same time. Concerning the upper threshold level $X_2(\theta)$, we find that

$$\frac{dX_2}{d\theta} = \frac{(n-1)\, n}{\delta \left(1+n\right)^2} > 0.$$

Thus an increase in $\theta$ raises threshold stock level at which extraction proceeds as if agents were playing a static game.

**Remark 2:** **(i)** The distance between the upper threshold and the waiting threshold, $X_2(\theta) - X_1(\theta)$, is increasing in $\theta$, **(ii)** In the interior of the interval $(X_1, X_2)$, the slope of the equilibrium strategy is independent of $\theta$ :

$$\frac{d\phi_c(X;\theta)}{dX} = \frac{(2\delta - r)\,(n+1)}{2n^2}, \text{for } X \in (X_1, X_2).$$

It follows that at any given $X$ such that $0 < \phi_c(X;\theta) < c_s(\theta)$, an increase in $\theta$ to $\theta' > \theta$ will shift *uniformly* the upward-sloping section of the graph of $\phi(X;\theta)$ by an amount independent of $X$ :

$$\begin{aligned}
\phi_c(X;\theta') - \phi_c(X;\theta) &= \left[X_1(\theta) - X_1(\theta')\right] \frac{(2\delta - r)\,(n+1)}{2n^2} \\
&= \left[\frac{\theta' - \theta}{1+n}\right] \frac{(2\delta + (n-1)\, r)}{2\delta n^2} > 0
\end{aligned}$$

As illustrated in Figure 1, this vertical shift is smaller than the vertical shift in the horizontal part of the exploitation strategy

$$c_s(\theta') - c_s(\theta) = \frac{\theta' - \theta}{1+n}.$$

This is consistent with the continuity of the exploitation strategy.

We conclude that an increase in $\theta$ results in an increase in extraction (see Figure 1). When relative output is the signal for status, status concern exacerbates the tragedy of the commons.

**Remark 3:** The slope of the aggregate exploitation function, $n\phi_c(X;\theta)$, is steeper than the slope $\delta$ of the tent-shaped biological growth function

$$\frac{dn\phi_c(X;\theta)}{dX} = \frac{(2\delta - r)(n+1)}{2n} > \delta$$

where the strict inequality follows from $\delta > (1+n^2)r/2$ (Assumption A1). This, together with the fact that $nc_s(\theta) > \delta X_2(\theta)$, shows that there is a locally stable steady-state stock $X^{\theta}_{1,\infty}$ to the *left* of the maximum-sustainable yield stock $X_y$ (See Figure 2). At $X^{\theta}_{1,\infty}$, the upward-sloping part of the graph of $n\phi_c(X;\theta)$ cuts the line $\delta X$ from below. If in addition $nc_s < \delta X_y$, then there are two other interior steady-state stocks, denoted by $X^{\theta}_{2,\infty}$ and $X^{\theta}_{3,\infty}$, generated by the intersection of the horizontal line $nc_s$ with the tent-shaped graph of $F(X)$, such that $X^{\theta}_{1,\infty} < X^{\theta}_{2,\infty} < X_y < X^{\theta}_{3,\infty}$. (See Figure 3). The steady-state equilibrium at stock level $X^{\theta}_{2,\infty}$ is unstable, and the one at stock level $X^{\theta}_{3,\infty}$ is stable. Thus an increase in $\theta$ always decreases the stable steady-state stock levels. We have thus established the following Proposition.

**Proposition 1: (Relative output concern exacerbates the tragedy of the common)**

*When agents are motivated by status concern in relative output ($\theta > 0$), the equilibrium exploitation strategy is never below the one obtained in the absence of status concern ($\theta = 0$). It lies strictly above the latter for $X > X_1(\theta)$. Locally stable steady-state stock levels fall as $\theta$ increases.*

We now turn to the case where the status concern is based on relative profits. The equilibrium strategy will be denoted by $c = \phi_p(X, \beta)$, where the subscript $p$ refers to profit-based status concern.

# 4 Relative profit as the only signal of status: $\theta = 0$ and $\beta \geq 0$

## 4.1 Equilibrium strategies when agents are concerned about relative profits

In Lemma 2 below, we show that when $\beta > 0$ and $\theta = 0$, the equilibrium strategy $c = \phi_p(X, \beta)$ has properties that are somewhat different from the strategy $c = \phi_c(X, \theta)$ described in Lemma 1 of the previous section. First, the exploitation is a continuous, non-decreasing, and piece-wise linear function of the stock. Second, the two threshold levels of stock, denoted by $X_{1p}(\beta)$ and $X_{2p}(\beta)$, where $0 < X_{1p}(\beta) < X_{2p}(\beta)$, are such that

(a) For all $X \in [0, X_{1p}(\beta)]$, all agents refrain from exploitation, allowing the resource stock to grow.

(b) For all $X \in [X_{1p}(\beta), X_{2p}(\beta)]$, the exploitation is a linear and increasing function of the resource stock. An increase in $\beta$ will rotate this positively-sloped section of the equilibrium strategy; see Figure 4. (This rotation result is in sharp contrast to the parallel shift result in Lemma 1.)

(c) For all $X \geq X_{2p}(\beta)$, the agents behave as if the resource stock had no value.

In order to focus on the interesting cases, we make the following assumption.

**Assumption A2:** *The intrinsic growth rate $\delta$ is sufficiently great, such that*

$$\delta > \max\left\{\frac{(1+n^2)\,r}{2}, \frac{a\left(1+(1+\beta)^2 n^2\right)}{X_y\,(1+(1+\beta)\,n)^2}\right\} \tag{6}$$

and

$$\beta < \frac{1}{n}\sqrt{\frac{2\delta}{r} - 1} \tag{7}$$

The first part of inequality (6) ensures, in the case where $\beta = 0$, that no one has an incentive to drive the resource to extinction ($X_{1p}(0) > 0$), because the intrinsic rate of growth, $\delta$, is sufficiently high relative to the rate of discount, magnified by the status-concern parameter $\beta$. When $\beta > 0$ we also require inequality **(7)** to ensure that the threshold $X_{1p}(\beta)$ is nonnegative**.** The second part of the inequality (6) ensures that the 'upper threshold' $X_{2p}(\beta)$ is smaller than the maximum-sustainable-yield stock, $X_y$.

**Lemma 2:** *Under Assumption A2, the following exploitation strategy, adopted by all agents, is a Markov-perfect equilibrium*

$$\phi_p(X;\beta) = \begin{cases} 0 & \text{for } X \le X_{1p}(\beta) \\ (X - X_{1p}(\beta)) \frac{c_{sp}(\beta)}{X_{2p}(\beta) - X_{1p}(\beta)} & \text{for } X \in [X_{1p}(\beta), X_{2p}(\beta)] \\ c_{sp}(\beta) & \text{for } X \ge X_{2p}(\beta) \end{cases}$$

*where $c_{sp}$ is the output level that the representative oligopolist subject to profit status concern would choose if the game were a static game:*

$$c_{sp}(\beta) = \frac{a(1+\beta)}{1+n(1+\beta)}.$$

*The 'waiting threshold' $X_{1p}(\beta)$ is given by*

$$X_{1p}(\beta) = \frac{a\left(2\delta - \left(1 + (1+\beta)^2 n^2\right) r\right)}{\delta\left(1 + (1+\beta)n\right)^2 (2\delta - r)}.$$

*The upper threshold $X_{2p}(\beta)$ is given by*[9]

$$X_{2p}(\beta) = \frac{a\left(1 + (1+\beta)^2 n^2\right)}{\delta\left(1 + (1+\beta)n\right)^2}.$$

*In particular, the positively-sloped section of the strategy $\phi_p(X;\beta)$ becomes flatter when $\beta$ increases (Figure 4).*

**Proof:** Omitted.

Using Assumption A2 it can be shown that the slope of the aggregate exploitation function is greater than $\delta$ and thus the line $n(X - X_{1p}(\beta)) \frac{c_{sp}}{X_{2p}(\beta) - X_{1p}(\beta)}$ that represents the aggregate exploitation $n\phi_p(X;\beta)$ cuts the line $\delta X$ from below. The intersection occurs at the point $X_{1,\infty}^{\beta}$ given by

$$X_{1,\infty}^{\beta} = \frac{n\frac{c_{ps}}{X_{2p} - X_{1p}} X_{1p}(\beta)}{n\frac{c_{ps}}{X_{2p} - X_{1p}} - \delta} > 0. \tag{8}$$

Let us show that $X_{1,\infty}^{\beta}$ is indeed a steady-state stock level. First, by direct computation, it can be shown that

$$X_{1,\infty}^{\beta} - X_{2p}(\beta) = 2an(1+\beta)\frac{n(1+\beta) - 1}{(n(1+\beta)+1)^2 (r(n(1+\beta)+1) - 2\delta)} \tag{9}$$

and therefore using the first part of Assumption A2 we have

$$X_{1,\infty}^{\beta} - X_{2p}(\beta) < 0 \text{ for all } n > 1 \text{ and } \beta \ge 0. \tag{10}$$

Second, we note that Assumption A2 implies that $X_{1,\infty}^{\beta} < X_y$**,** and $\delta X_{1,\infty}^{\beta} < nc_{sp}(\beta)$**.** Thus $X_{1,\infty}^{\beta}$ is a steady-state stock level.

[9] The distance betwen $X_{2p}(\beta)$ and $X_{1p}(\beta)$ can be shown to equal $\frac{2an^2}{(2\delta - r)}\left(n + \frac{1}{(\beta+1)}\right)^{-2}$ which is increasing in the status concern parameter $\beta$.

We are now ready to prove a novel result. Unlike Proposition 1, which states that relative-output concern unambiguously exarcerbates the tragedy of the commons, the following Proposition shows that if relative profit serves as the signal of status there exists an interval of stock size such that an increase in the status concern parameter $\beta$ will lead to lower exploitation in that interval.

**Proposition 2:**

(i) *Assume $n \geq 3$. Then there exist $X'_\beta$ and $X''_\beta \in (X_{1p}, X_{2,p})$ such that*

$$\phi_p(X, \beta) < \phi_p(X, 0) \text{ for all } X \in \left(X'_\beta, X''_\beta\right)$$

*That is, at any stock level inside the interval $\left(X'_\beta, X''_\beta\right)$, status concern based on relative profits results in a smaller extraction than under the absence of status concern.*

*(ii) If $n = 2$, the above conclusion still holds, provided Assumption 2 is strengthened by the requirement that $\delta > \max(\delta_1, \delta_2)$, where $\delta_1 \equiv (3 + 4\beta)(r/2\beta)$ and $\delta_2 \equiv (4(1 + \beta)^2 + 1)(r/2)$.*

**Proof:** see Appendix B for part (i), and Appendix C for part (ii). ■

Proposition 2 constitutes the main contribution of this paper. In sharp contrast to the existing literature, status concern or social status may alleviate the tragedy of the commons (see Figure 4). The discussion of the intuition behind this result is postponed until Section 5.

## 4.2 Profit-based status and steady-state stocks

How many steady-state stocks are there for each given $\beta$? How do they compare with those corresponding to $\beta = 0$?

We consider three cases.

**Case 1: (Small MSY)**. Assume that the maximum-sustainable yield, $\delta X_y$, is small, in the sense that

$$nc_{sp}(\beta) > \delta X_y \text{ for all } \beta \geq 0.$$

In this case, there is exactly one interior steady state, and it is stable. An increase in $\beta$ will result in a smaller steady state stock. This case is illustrated in Figure 5A.

**Case 2: (Intermediate MSY).** An intermediate maximum-sustainable yield, $\delta X_y$, is such that the following conditions hold: (i) the maximum-sustainable yield is greater than the static Cournot oligopoly output in the absence of status concern

$$nc_{sp}(\beta = 0) < \delta X_y$$

and (ii) there exists some $\beta_L$ satisfying Assumption A2, and for all $\beta > \beta_L$, the maximum-sustainable yield is smaller than the static Cournot oligopoly output under strong relative-profit status concern

$$nc_{sp}(\beta) > \delta X_y \text{ for all } \beta > \beta_L.$$

In this case, starting at $\beta = 0$, a sufficiently large increase in $\beta$ changes an economy with three steady states to one with a unique (and lower) steady state. This case is illustrated in Figure 5B.

**Case 3: (Large MSY).** A large maximum-sustainable yield, $\delta X_y$, is such that it exceeds the static Cournot oligopoly output under relative-profit status concern, for all $\beta$ that satisfy Assumption A2:

$$\delta X_y > nc_{sp}(\beta).$$

In this case, for all relevant values of $\beta$, there are always three interior steady states with an unstable one in between two stable ones. In addition, there is a new feature: status concern can cause a bifurcation, in a sense that a small change in the parameter $\beta$ causes a large change in an equilibrium path. Let us show this graphically.

Consider the steady-state stock level $X_{1,\infty}^{\beta}$ defined by equation (8). From (10), we have that $X_{1,\infty}^{\beta} < X_{2p}(\beta)$. This along with the fact that the equilibrium strategy is strictly increasing over $(X_{1p}(\beta), X_{2p}(\beta))$ yields (i) $X_{1,\infty}^{\beta} < X_y$ and (ii) $\delta X_{1,\infty}^{\beta} < nc_{ps}(\beta)$.

Given $\beta$, there exist three interior steady-state stock levels, $X_{1,\infty}^{\beta} < X_{2,\infty}^{\beta} < X_{3,\infty}^{\beta}$, where

$$X_{2,\infty}^{\beta} = \frac{nc_{ps}(\beta)}{\delta}$$

and $X_{3,\infty}^{\beta}$ is solution to

$$\left(\frac{X_y}{\overline{X} - X_y}\right)\left(\overline{X} - X_{3,\infty}^{\beta}\right) = \frac{nc_{ps}(\beta)}{\delta}.$$

The steady state $X_{2,\infty}^{\beta}$ is unstable, and the other two steady states, $X_{1,\infty}^{\beta}$ and $X_{3,\infty}^{\beta}$, are stable. Figure 5C shows that an increase in $\beta$ results in a decrease of the steady stock $X_{1,\infty}^{\beta}$ of the resource. This is in line with the results obtained in Long and McWhinnie (2012). However in our framework, a new possibility arises, as depicted in Figure 5C. Suppose that in the absence of status concern there are three steady states and that the initial stock is $X = X_{2,\infty}^{\beta=0} + \varepsilon$; then clearly, the stock eventually converges to the steady state $X_{3,\infty}^{\beta=0}$. However in the case where agents experience status concern, with the same initial stock $X = X_{2,\infty}^{\beta=0} + \varepsilon$, the stock will converge to the small steady state $X_{1,\infty}^{\beta}$.

In all cases 1-3, for the smallest interior steady state $X_{1,\infty}^{\beta}$, an increase in the concern over social status will result in a decrease of the steady state stock of the resource, as can be seen from

$$\frac{\partial X_{1,\infty}^{\beta}}{\partial \beta} = -2a\frac{n}{\delta}\frac{(\delta - r)\left(2\delta + r\left(n^2(1+\beta)^2 - 1\right)\right)}{(n + n\beta + 1)^2(2\delta - (1 + n(1+\beta))r)^2} < 0.$$

Our analysis has shown that the long-run and the short-run impacts of profit based status concern may differ. Whether the short-run impact is important or not clearly depends on the discount rate. A higher discount rate corresponds to the case where agents care very little about the future. Interestingly, it can be shown that as the future is valued less (i.e. when $r$ is higher) the interval of stocks for which we obtain a reversal of the standard impact of status concern expands: $\Delta \equiv X_{\beta}'' - X_{\beta}'$ is a increasing function of the discount rate $r$. (See Appendix E for a proof.)

# 5 Catch-size based status concern versus profit-based status concern

We have seen that the effect of status concern on the rate of resource exploitation depends on whether it is based on comparison of catches (an increase in the parameter $\theta$) or comparison of profits (an increase in the parameter $\beta$). An increase in $\theta$ shifts the positively-sloped portion of the exploitation strategy upwards by a constant in the interval $(X_1, X_2)$. In contrast, an increase in $\beta$ leads to a clockwise rotation of the positively-sloped portion of the exploitation strategy. What are the reasons for this difference in response to parameter changes? The key to the answer is that in the case comparison of catches, the ‘loss of self-esteem’ if one falls behind is *linear* in one's exploitation rate $c_i$, while in the case of comparison of profits, this loss is *quadratic* in $c_i$. To avoid such a loss of self-esteem, in the former case, an increase in $\theta$ will give agent $i$ an incentive to increase $c_i$ by an amount that is independent of the stock size $X$ (as long as $X \in (X_1, X_2)$): in the agent's first-order condition, $\theta$ does not interact with $X$. In contrast, in the case of status concern with respect to relative profit, an increase in $\beta$ gives agent $i$ an incentive to increase $c_i$ only if the industry output is small (due to a small $X$), because this would increase $\pi_i$; but if the industry output is large, an increase in $c_i$ may not be called for, given that all other agents reduce their $c_j$. These considerations become clearer as we now look a bit more closely (though only heuristically) at the Hamilton-Jacobi-Bellman equations for the two cases.

In the case of status concern in relative catch, the HJB equation of agent $i$ is

$$rV^i(X) = \max_{c_i} \left\{ [a - (n-1)\phi(X) - c_i]\, c_i + \theta(c_i - \phi(X)) + V_X^i\, [F(X) - (n-1)\phi(X) - c_i] \right\}$$

The first-order condition is

$$(a + \theta) - 2c_i = V_X^i(X; \theta) + (n-1)\phi(X)$$

To get an approximate sense of the response of $c_i$ to an increase in $\theta$, let us suppose that the marginal value of the stock, $V_X^i$ , is separable in $X$ and $\theta$, so that $\left[V_X^i(X;\theta) - V_X^i(X;\theta')\right] = \zeta(\theta) - \zeta(\theta')$, for some function $\zeta(.)$. (This will be verified in Appendix D, for $X \geq X_1(\theta)$.) Then the first-order condition indicates that an increase in $\theta$ will lead to an increase in $c_i$ by an amount that is independent of $X$ (given that $\phi(X)$ increases by an amount independent of $X$). That is, for $\theta' \neq \theta$,

$$(a + \theta) - c_i^{\theta} - \left[(a + \theta') - c_i^{\theta'}\right] = \zeta(\theta) - \zeta(\theta') + (n-1)\left[c_j^{\theta} - c_j^{\theta'}\right]$$

independent of $X$.

In contrast, in the case of status concern in relative profit, the HJB equation of agent $i$ is

$$\begin{aligned} rV^i(X) &= \max_{c_i} (1+\beta)\, [a - (n-1)\phi(X) - c_i]\, c_i \\ &\quad -\beta\, [a - (n-1)\phi(X) - c_i]\, \phi(X) + V_X^i\, [F(X) - (n-1)\phi(X) - c_i] \end{aligned}$$

The first-order condition gives

$$a - 2c_i = \frac{V_X^i + [(n-1) + \beta(n-2)]\, \phi(X)}{1+\beta}$$

Again, to get an approximate sense of the response of $c_i$ to an increase in $\beta$, let us suppose that the change in the marginal value of the stock, $V_X^i$ , is independent of $X$. Then an increase in $\beta$ would lead to an increase in the denominator, which would necessarily require an increase in $c_i$ only if the numerator were constant. However, the numerator is not a constant: it contains the term $\beta(n-2)\phi(X)$, which offsets the increase in the denominator if $X$ is large.

At first sight, one might be tempted to conjecture that profit-based status concern leads to a more agressive behavior than an output-based status concern. When a player increases her production, she is increasing her own instantaneous profit and at the same time diminishing the profits of the rest of the industry. Indeed the profit-based status concern term is

$$\beta \left( (a_i - C)\, c_i - \frac{\Sigma_{j \neq i}\, (a - C)\, c_j}{n-1} \right).$$

Thus one might have expected that if output-based status concern is conducive to voracious behavior, profit-based status concern would even be more so. However our result shows that this intuition may be misleading, because it ignores the stock effect. In a dynamic game the use of feedback rules gives firms an additional incentive to overproduce when the equilibrium strategies are increasing functions of the stock. This is due to the fact that a marginal extraction by a firm, through its impact on the stock, induces a decrease of the extraction of the other firms. The larger the slope of the equilibrium strategies the larger this incentive to overproduce. We can show that the status concern's impact on the slope of the equilibrium strategies differs between output-based and profit-based status concern. While output-based status concern does not impact the slope of the equilibrium strategy thereby leaving feedback incentive for overproduction unchanged, profit-based status concern modifies the slope of the equilibrium strategy. Indeed the slope is given by

$$\frac{c_{sp}(\beta)}{X_{2p}(\beta) - X_{1p}(\beta)} = \frac{2\delta - r}{2n^2}\left(n + \frac{1}{1+\beta}\right)$$

which is a decreasing function of $\beta$. Therefore an increase in $\beta$ diminishes the feedback incentive to overproduce and thus, for some range of initial stocks, this effect can move the equilibrium outcome closer to that of a cartel.[10]

While we have examined output and profit based status concerns separately, our results allow to us to have insights into a situation where status concern is based on both relative output and relative profits. Indeed one can expect that, in the short run, over some interval of stock size, status concern may still lead to a decrease in extraction provided the role played by relative output is small compared to relative profits. However since both sources of status concern lead to a decrease in the steady state stock, we can expect that when both sources of status concern coexist the steady state stock of the resource will decline.[11]

# 6 Status concern and welfare

In this section we will show that the impact of status concern on the discounted sum social welfare, defined as the sum of consumers' surplus and producers' surplus, is ambiguous and depends on the *initial* level of the resource of stock. This is true for both output-based and profit-based status concern. To economize on space we only treat below the case of output-based status concern.

The instantaneous consumers' surplus given by $\frac{1}{2}\left(n\phi_c\left(X;\theta\right)\right)^2$. The value of the discounted stream of instantaneous consumers' surplus is

$$CS\left(X_0;\theta\right) = \int_0^\infty e^{-rt}\frac{1}{2}\left(n\phi_c\left(X;\theta\right)\right)^2 dt$$

The discounted stream of payoffs of firm $i$ is

$$V_i(X_0;\theta) = \int_0^\infty e^{-rt}\left[(a-C)c_i + \theta\left(c_i - \frac{\sum_{j\neq i} c_j}{n-1}\right)\right] dt$$

where $c_i = \phi_i(X;\theta)$ and $C = \sum_j \phi_j(X;\theta)$.

[10] We thank a reviewer for providing this insightful interpretation.

[11] It would be interesting to examine under which conditions status concern may lead to an increase in the steady stock. Possible modifications to our framework that could be interesting to investigate include the case where property rights can be allocated (Colombo and Labrecciosa, 2013) or the case of price competition instead of competition in quantities (Colombo and Labrecciosa, 2015).

In the literature on social welfare when agents are mutually envious or mutually benevolent, there are two opposing views on whether the pleasure or pain derived from such concerns should be counted as part of social welfare (see, e.g., Bergstrom (2007) for a discussion). However, it turns out that because in our specification the envy term $\theta(c_i - c_{-i})$ is linear in $c_i$ and $c_{-i}$, when we add up these terms over all firms, they sum up to zero. (This is true even if the firms have different costs, $b_i \neq b_j$). Nevertheless this does not mean that envy does not matter: recall that the strategy $\phi_i(X;\theta)$ depends on $\theta$.

Under symmetry, the social welfare is

$$SW(X;\theta) = nV(X;\theta) + CS(X;\theta).$$

Assume we are in a situation as depicted in case 3: we have three positive steady states under status concern as well as in the absence of status concern.

Consider first the simple case where the initial stock is $X > X_{2,\infty}^{(\theta)}$ . Then we have the outcome of a static game played from $t = 0$ to $\infty$. In terms of consumption, we have

$$n\phi_c(X;\theta) = nc_s(\theta) > n\phi_c(X;0) = nc_s(0)$$

thus consumers' surplus under status concern is larger than in the absence of status concern. Regarding the discounted sum of profits $V(X;\theta)$ ,since the firms' output is a constant that is greater than the static oligopoly level, we can easily see that

$$V(X;\theta) < V(X;0) \text{ for all } X > X_{2,\infty}^{(\theta)}.$$

The market price is constant, at

$$p = A - nc_s(\theta)$$

and the profit per firm is

$$(p-b)c_s(\theta) = [a - nc_s(\theta)]\, c_s(\theta)$$

In this case, instantaneous social welfare is simply the area under the market demand curve, up to output level $nc_s(\theta)$, minus the extraction costs. Hence, for $X > X_{2,\infty}^{(\theta)}$, social welfare under oligopoly is

$$\begin{aligned} SW(X;\theta) &= \frac{1}{r}\left[\frac{1}{2}(nc_s(\theta))^2 + [a - nc_s(\theta)]\, nc_s(\theta)\right] \\ &= \frac{1}{r}\left[anc_s(\theta) - \frac{1}{2}(nc_s(\theta))^2\right] \end{aligned}$$

The RHS expression is increasing in output as long as industry output is below the level $C^*$ defined by

$$C^* = a$$

Recalling that $c_s(\theta) = \frac{a+\theta}{1+n}$, we conclude that if $\theta$ satisfies

$$\frac{n(a+\theta)}{1+n} < a$$

then a small increase in status concern brings consumption closer the social optimal level. Therefore we can state that when the initial stock exceeds $X_{2,\infty}^{(\theta)}$, social welfare under status concern exceeds social welfare in the absence of status concern provided $n\theta < a$.

To establish that the impact of status concern on social welfare can be ambiguous we now show that if $X < X_{2,\infty}^{(\theta)}$, social welfare under status concern can be smaller than in the absence of status concern. We check that this is true for a particular level of the stock of the resource, i.e. $X_1(0)$.

We denote by $V^i$ the discounted sum of profits of player $i$ denoted. It coincides with her discounted sum of utility in a symmetric equilibrium, and is given by

$$V^i(X;\theta) = V(X;\theta) \equiv \int_0^\infty e^{-rt} u(\phi_c(X;\theta), n\phi_c(X;\theta))dt.$$

The exact functional form of this expression, for different levels of $X$, is given in Appendix D.

We show in Appendix D that, at $X = X_2(\theta)$,

$$SW(X_2(\theta);\theta) - SW(X_2(\theta);0) < 0$$

and that

$$SW(X;\theta) - SW(X;0) < 0 \text{ for all } X \in [X_1(0), X_2(\theta)].$$

Thus, in the range of stocks where the equilibrium extraction strategies are strictly increasing functions of the stock, status concern results in a loss in social welfare. Since we have shown that when the resource is abundant status concern results in a gain social welfare for $\theta < a/n$, and since $SW(X;\theta) - SW(X;0)$ is continuous with respect to $X$ we can state that, for each $\theta$ there exists $\tilde{X}(\theta) \in [X_2(\theta), X_{2,\infty}^{(\theta)})$ such $SW(X;\theta) - SW(X;0) = 0$.

# 7 Conclusion

We have shown that when agents have oligopoly power in the goods market, the effect of status seeking on common property resource exploitation depends on whether the signal of status is relative output or relative profit. In the former case, the result is standard: more concern over status means more aggressive exploitation and lower steady-state output. In the latter case, the results are much more nuanced. There is a range of stock levels where an increase in the status concern parameter with respect to relative profit will result in *slower* rate of exploitation. However, in the case of a unique interior steady state, as the stock declines, eventually the lower limit of that range is reached, and a *switch* occurs: the rate of exploitation under status concern becomes greater than under non-status concern, and the long run outcome is a lower steady-state stock and lower exploitation.

Status concern leads to lower producers' welfare, because each firm has to exert more effort without being able to achieve a change in its relative status. This was aptly depicted by Lewis Carroll in his famous children book, Through the Looking Glass:"*The Red Queen seized Alice by the hand and dragged her, faster and faster, on a frenzied run through the countryside, but no matter how fast they ran they always stayed in the same place.*"[12]In our model, we found that whether the wasted efforts increase with status concern depends on whether status concern is based on relative catch or on relative profit. In the latter case, we were able to prove a novel result: within a certain range of stock level, the wasted efforts are decreasing in the strength of status concern over relative profit. Consumers, on the other hand, benefits from status

[12] See Dawkins (1986, p. 183) for the Red Queen effect.

concern among firms when the status concern results in higher industry output, and therefore lower price. We conclude that the effect on status concern on social welfare depends on the initial stock level.

**Appendix A**

The vector $(\phi_c, .., \phi_c)$ constitutes a symmetric Markov-Perfect Nash Equilibrium if there exist $n$ value functions $V_1, .., V_n$ continuously differentiable such that the function $\phi_c$ is solution to the problem:

$$rV_i(X;\theta) = \underset{\phi_i}{Max}\{(a - b(\phi_i + (n-1)\phi_c))\phi_i + \theta(\phi_i - \phi_c) + V_i'(X)(F(X) - (\phi_i + (n-1)\phi_c))\} \tag{11}$$

with $i = 1, .., n$. We use the undetermined coefficients technique (see Dockner et al. 2000) to determine the value functions $V_1, .., V_n$. The originality of the equilibrium we exhibit is that it combines the two solutions that we obtain from the standard application of the undetermined coefficients technique. The transition from one solution to another is determined by requiring that the value function is continuously differential at the level of stock where the transition occurs.

Consider the following value function $V(X;\theta)$

$$V(X;\theta) = \begin{cases} W(X_1(\theta);\theta)\left(\dfrac{X}{X_1(\theta)}\right)^{\frac{r}{\delta}} & \text{if} \quad 0 \leq X < X_1(\theta) \\ W(X;\theta) & \text{if} \quad X_1(\theta) \leq X < X_2(\theta) \\ \dfrac{\pi_s}{r} & \text{if} \quad X_2(\theta) \leq X \end{cases} \tag{12}$$

where $\pi_s = \frac{(a-n\theta)(a+\theta)}{(1+n)^2}$ and

$$W(X;\theta) = EX^2 + DX + G$$

with

$$E = -\frac{(1+n)^2(2\delta - r)}{4n^2}$$
$$D = -2EX_2(\theta)$$

and

$$G = \frac{\pi_s}{r} + EX_2(\theta)^2.$$

The rest of the proof consists of showing that $(i)$ the value function above, $V(X;\theta)$, is continuously differentiable with respect to $X$ and that $(ii)$ the function $\phi_c$ given by (5) is solution of the problem (11) where $V_1(X) = .. = V_n(X) = V(X)$.

$(i)$ Proof that $V(X;\theta)$ is continuously differentiable in $X$:
The function $V(X;\theta)$ is clearly continuously differentiable over $[0, X_1(\theta))$, $(X_1(\theta), X_2(\theta))$, and $(X_2(\theta), \infty)$ respectively with:

$$V'(X;\theta) = \begin{cases} \frac{r}{\delta_1(\theta)}\left(\frac{X}{_1(\theta)}\right)^{\frac{r}{\delta}-1} W(X_1(\theta);\theta) & \text{if} \quad 0 \leq X < X_1(\theta) \\ W'(X;\theta) & \text{if} \quad X_1(\theta) \leq X < X_2(\theta) \\ 0 & \text{if} \quad X_2(\theta) \leq X \end{cases} \tag{13}$$

We need to check that the function $V(X;\theta)$ is continuously differentiable at $X_1(\theta)$ and at $X_2(\theta)$.

Let us first check that $V(X;\theta)$ is continuous at $X_1(\theta)$ and at $X_2(\theta)$. We have

$$\underset{X \to X_1(\theta),\ X < X_1(\theta)}{lim} V(X;\theta) = W(X_1(\theta);\theta) = \underset{X \to X_1(\theta),\ X > X_1(\theta)}{lim} V(X;\theta)$$

and

$$\lim_{X \to X_2(\theta),\ X<X_2(\theta)} V(X;\theta) = W(X_2(\theta);\theta) = \frac{(a-n\theta)(a+\theta)}{(1+n)^2 r} = \lim_{X \to X_2(\theta),\ X>X_2(\theta)} V(X;\theta).$$

Therefore the function $V$ is continuous at $X_1(\theta)$ and $X_2(\theta)$.

We now check that $V'$ (derivative of $V$ with respect to $X$) is continuous at $X_1(\theta)$ and $X_2(\theta)$. We have

$$\lim_{X \to X_1(\theta),\ X<X_1(\theta)} V'(X;\theta) = \frac{rW(X_1(\theta);\theta)}{\delta X_1(\theta)}$$

It can be checked that

$$\frac{rW(X_1(\theta);\theta)}{\delta X_1(\theta)} = W'(X_1(\theta);\theta) = a$$

and thus

$$\lim_{X \to X_1(\theta),\ X<X_1(\theta)} V'(X;\theta) = \lim_{X \to X_1(\theta),\ X>_1(\theta)} V'(X;\theta) \text{ , i.e. } V' \text{ is continuous at } X_1(\theta)$$

Moreover

$$\lim_{X \to X_2(\theta),\ X<X_2(\theta)} V'(X;\theta) = EX_2(\theta) + D = 0 \text{ i.e. } V' \text{ is continuous at } X_2(\theta)$$

and thus $V'$ is continuous at $X_1(\theta)$ and $X_2(\theta)$.

Therefore the function $V(X;\theta)$ is continuously differentiable with respect to $X$ over $[0,\infty)$.

$(ii)$ We now show that the function $\phi_c$ given by (5) is solution of the problem (11) where $V_1(X;\theta) = V_2(X;\theta) = .. = V(X;\theta)$.

Let $V_i(X;\theta) = V(X;\theta)$ for $i = 1, ..\ n$.

For $X \geq X_1(\theta)$ the problem (11) admits an interior solution. The function $\phi_i^*$ is then given by the following first-order condition of the problem (11):

$$(a - b(n-1)\phi_c) - 2b\phi_i + \theta - V_i'(X;\theta) = 0 \text{ with } i = 1, .., n. \tag{14}$$

For a symmetric equilibrium we have

$$\phi_{c,i}(X;\theta) = \phi_c(X;\theta) = \frac{a+\theta-V'(X;\theta)}{(n+1)b} \text{ for all } i = 1, .., n \tag{15}$$

Substituting into (11) gives

$$rV = \left(a+\theta-bN\frac{a+\theta-V'}{(n+1)b}\right)\frac{a+\theta-V'}{(n+1)b} + V'\left(F(X) - n\frac{a+\theta-V'}{(n+1)b}\right) \tag{16}$$

or after simplification

$$rV = \frac{\left(a+\theta-n^2V'\right)(a+\theta-V')}{(n+1)^2 b} + V'F(X) \tag{17}$$

It can be checked that the value function $V$ satisfies the differential equation above for all $X \geq X_1(\theta)$.

Substituting $V'$ from (13) into (15) yields exactly $\phi_c$. The level of stock $X_2(\theta)$ is determined such that $V$ is continuously differentiable in the neighborhood of $X_2(\theta)$.

For $X < X_1(\theta)$, the problem (11) has the corner solution: $\phi_c(X;\theta) = 0$. It can be checked that the function $V(X;\theta)$ given by (12) satisfies the differential equation obtained after substitution of (15) into (11) ■

**Appendix B**

**Proposition 2:** *Assume $n \geq 3$. Then there exist $X'_\beta$ and $X''_\beta \in (X_{1p}, X_{2,p})$ such that*

$$\phi_p(X, \beta) < \phi_p(X, 0) \text{ for all } X \in \left(X'_\beta, X''_\beta\right)$$

*That is, at any stock level inside the interval $\left(X'_\beta, X''_\beta\right)$, status concern results in a smaller extraction than under the absence of status concern.*

**Proof**

We will make use of the following facts:

(i) The horizontal part of the exploitation function $\phi_p(X;\beta)$ is increasing in $\beta$.

(ii) The slope of the equilibrium exploitation function $\phi_p(X;\beta)$ is a decreasing function of $\beta$.

(iii) The upper threshold, $X_{2p}$, is increasing in $\beta$

$$\frac{\partial X_{2p}}{\partial \beta} = \frac{\partial\left(\frac{a\left(1+(1+\beta)^2 n^2\right)}{\delta(1+(1+\beta)n)^2}\right)}{\partial \beta} = \frac{2an(n+n\beta-1)}{\delta\left(n+n\beta+1\right)^3} > 0$$

and

(iv) The lower threshold is decreasing in $\beta$

$$\frac{\partial X_{1p}}{\partial \beta} = \frac{\partial\left(\frac{a\left(2\delta-\left(1+(1+\beta)^2 n^2\right)r\right)}{\delta(1+(1+\beta)n)^2(2\delta-r)}\right)}{\partial \beta} = -\frac{2an\left(2\delta - r + nr\left(1+\beta\right)\right)}{\delta\left(2\delta-r\right)\left(n\left(1+\beta\right)+1\right)^3} < 0$$

This implies that in the range of $X$ with srictly positive extraction, the graphs of the extraction strategy under status concern and without status concern must either (a) intersect each other twice (once in the linear increasing phase of the extraction policy and once in the phase where the no-status concern policy is flat) or (b) have no intersection. We show below that (b) cannot happen if $n \geq 3$,

Let us show that the two policies must intersect on the interval $[X_{1p}, X_{2p}]$. Let $\phi_p(X;\beta)$ denote the equilibrium strategy under status concern. We seek to determine the sign of the gap

$$G(X) = \phi_p(X, \beta) - \phi_p(X, 0)$$

at the stock level $X_{2p}(\beta = 0)$, i.e., at

$$X = X_{2p}|_{\beta=0} = \frac{a\left(1+n^2\right)}{\delta\left(1+n\right)^2}.$$

If this sign is negative, then we are done.

After some algebraic manipulations, we obtain

$$G\left(X_{2p}|_{\beta=0}\right) = \frac{a}{n}\frac{\beta\Delta}{\delta\left(\beta+1\right)\left(n+1\right)^2\left(n+n\beta+1\right)}$$

where

$$\Delta = \left(n\left(1+\beta\right) - n^2\left(1+\beta\right) + 2\right)\delta + r\left(n^2\left(1+\beta\right) - 1\right). \tag{18}$$

We wish to show that $\Delta$ is negative. The term $\left(n\left(1+\beta\right) - n^2\left(1+\beta\right) + 2\right)$ is negative for $n \geq 2$ and $\beta \geq 0$. Therefore, using Assumption A2, we have

$$\Delta \leq \left(n\left(1+\beta\right) - n^2\left(1+\beta\right) + 2\right)\frac{\left(1+\left(1+\beta\right)^2 n^2\right)r}{2} + r\left(n^2\left(1+\beta\right) - 1\right)$$

i.e.,

$$\Delta \leq \frac{1}{2}nr\left(\beta+1\right)P\left(\beta\right)$$

where

$$P\left(\beta\right) \equiv n^2\left(1-n\right)\beta^2 + 2n\left(n-n^2+1\right)\beta + \left(n^2-n^3+3n+1\right)$$

Notice that $P\left(\beta\right)$ is a polynomial of degree in 2 in $\beta$ with each coefficient negative for $n \geq 3$. Therefore we have $P\left(\beta\right) < 0$ for all $\beta \geq 0$. It follows that $\Delta < 0$ for $n \geq 3$. This implies that for $n \geq 3$ we have

$$\phi_p\left(\left.X_{2p}\right|_{\beta=0}, \beta\right) - \phi_p\left(\left.X_{2p}\right|_{\beta=0}, 0\right) < 0$$

which implies that $\phi_p\left(X,\beta\right)$ and $\phi_p\left(X,0\right)$ intersect twice for all values of $\delta$ that satisfy Assumption 2. This along with (i)-(iii) completes the proof ■.

**Appendix C**

For $n=2$, the expression for $\Delta$ in the proof of part (i) of Proposition 2 reduces to $\Delta = 3r + 4r\beta - 2\beta\delta$. Then $\Delta < 0$ which is true iff $\delta$ is greater than a critical value $\delta_1$

$$\delta > \frac{(3+4\beta)r}{2\beta} \equiv \delta_1$$

We deduce from Assumption A2 that $\delta > \delta_2$, where

$$\delta_2 \equiv \frac{r}{2}\left(1+\left(1+\beta\right)^2 4\right).$$

Thus, if $\delta_2 \geq \delta_1$, we can infer that $\Delta < 0$, and we are done.

Note that

$$\delta_2 - \delta_1 = \frac{1}{2}\frac{r}{\beta}\left(2\beta+3\right)\left(2\beta-1\right)\left(\beta+1\right)$$

Thus, if $\beta > 1/2$, then Assumption A2 yields $\Delta < 0$. When $\beta \leq \frac{1}{2}$, we state a weaker sufficient condition for $\Delta$ to be negative in the case $n=2$ :

$$\delta > \max\left(\delta_1, \delta_2\right).$$

Thus part (i) of Proposition 2 extends to the case $n=2$ provided that $\delta > \max\left(\delta_1,\delta_2\right)$.

**Appendix D**

We show below that

$$SW\left(X_1\left(0\right);\theta\right) - SW\left(X_1\left(0\right);0\right) < 0$$

where

$$SW\left(X;\theta\right) = nV\left(X;\theta\right) + CS\left(X;\theta\right).$$

The determination of $V\left(X;\theta\right)$ follows from the characterization of the equilibrium $\phi_c$. The details are very close to the characterization of the equilibrium in the absence in status concern (Benchekroun (2008) and are therefore omitted. The function $V\left(X;\theta\right)$ is given by

$$V\left(X;\theta\right) = \begin{cases} W\left(X_1\left(\theta\right);\theta\right)\left(\dfrac{X}{X_1\left(\theta\right)}\right)^{\frac{r}{\delta}} & \text{if} \quad 0 \leq X < X_1\left(\theta\right) \\ W\left(X;\theta\right) & \text{if} \quad X_1\left(\theta\right) \leq X < X_2\left(\theta\right) \\ \dfrac{\pi_s}{r} & \text{if} \quad X_2\left(\theta\right) \leq X \end{cases} \tag{19}$$

where $\pi_s = \frac{(a-n\theta)(a+\theta)}{(1+n)^2}$,

and

$$W(X;\theta) = EX^2 + DX + G$$

with

$$E = -\frac{(1+n)^2(2\delta - r)}{4n^2}$$

$$D = -2EX_2(\theta)$$

and

$$G = \frac{\pi_s}{r} + EX_2(\theta)^2.$$

Note that $W$ is continuous at $X_2(\theta)$

$$W(X_2(\theta),\theta) = EX_2(\theta)^2 - 2EX_2(\theta)^2 + \frac{\pi_s}{r} + EX_2(\theta)^2 = \frac{\pi_s}{r}.$$

To express the discounted sum of consumers' surplus as a function of the initial $X_t$, we use

$$CS(X_t;\theta) = \int_t^\infty e^{-r(\tau-t)}\frac{1}{2}\left(n\phi_c(X(\tau);\theta)\right)^2 d\tau,\ X(t) = X_t$$

Differentiate this expression wrt $t$

$$\frac{dCS(X_t,\theta)}{dt} = rCS(X_t,\theta) - \frac{1}{2}\left(n\phi_c(X(t);\theta)\right)^2$$

On the other hand,

$$\frac{dCS(X_t,\theta)}{dt} = CS_X\frac{dX}{dt} = CS_X\left[F - n\phi_c\right]$$

Thus $CS(X;\theta)$ is the sollution to the following differential equation

$$rH(X;\theta) = \frac{1}{2}\left(n\phi_c(X;\theta)\right)^2 + H_X(X;\theta)\left(F(X) - n\phi_c(X;\theta)\right)$$

with the boundary condition

$$H\left(X_{1,\infty}^{(\theta)};\theta\right) = \frac{1}{2r}\left(n\phi_c\left(X_{1,\infty}^{(\theta)};\theta\right)\right)^2.$$

The following lemma gives $CS(X;\theta)$ :

Lemma: Suppose the MSY is large enough so that three positive steady states exist. Consumers' surplus is given by

$$CS(X;\theta) = \begin{cases} WC(X_1(\theta);\theta)\left(\dfrac{X}{X_1(\theta)}\right)^{\frac{r}{\delta}} & \text{if} \quad 0 \le X < X_1(\theta) \\ WC(X;\theta) & \text{if} \quad X_1(\theta) \le X \le X_2(\theta) \\ \dfrac{1}{2r}\left(nc_s(\theta)\right)^2 + \left(\dfrac{X - \frac{nc_s(\theta)}{\delta}}{X_2(\theta) - \frac{nc_s(\theta)}{\delta}}\right)^{\frac{r}{\delta}}\left(WC(X_2(\theta);\theta) - \dfrac{1}{2r}\left(nc_s(\theta)\right)^2\right) & \text{if} \quad X_2(\theta) < X \le \frac{nc_s(\theta)}{\delta} \\ \frac{1}{2r}\left(nc_s(\theta)\right)^2 & \text{if} \quad \frac{nc_s(\theta)}{\delta} < X \end{cases}$$

Note that the function $CS(X;\theta)$ is convex and increasing over the interval $(X_1(\theta), X_2(\theta))$ because $k_2 > 0$. It is concave and non-decreasing for $X \in [0, X_1(\theta)]$ and for $X > X_2(\theta)$.

Proof:

For $X \in [X_1(\theta), X_2(\theta)]$ the solution is

$$WC(X;\theta) = \frac{k_0 + k_1 X + k_2 X^2}{\kappa} \tag{20}$$

where

$$\kappa = 8\delta^2 n(1+n)^2 r(2\delta + (n-1)r)$$

and

$$k_0 = (2\delta n - (n-1)r)(\beta n(2\delta + (n-1)r) + a\left(r\left(1+n^2\right) - 2\delta\right))^2$$

$$k_1 = 8\delta^2 n(1+n)^2 r(2\delta + (n-1)r)$$

$$k_2 = \delta^2(1+n)^4(2\delta - r)r(2\delta + (n-1)r).$$

For $X \in [X_2(\theta), X_{2,\infty}^{(\theta)}]$

$$CS(X;\theta) = \int_0^\infty e^{-rt}\frac{1}{2}\left(n\phi_c(X;\theta)\right)^2 dt$$

or

$$CS(X;\theta) = \int_0^{T(X;\theta)} e^{-rt}\frac{1}{2}\left(n\phi_c(X;\theta)\right)^2 dt + \int_{T(X;\theta)}^\infty e^{-rt}\frac{1}{2}\left(n\phi_c(X;\theta)\right)^2 dt$$

which can be written as

$$CS(X;\theta) = \frac{1}{2}\left(nc_s(\theta)\right)^2\frac{1-e^{-rT(X;\theta)}}{r} + e^{-rT(X;\theta)}\int_0^\infty e^{-rt}\frac{1}{2}\left(n\phi_c(X;\theta)\right)^2 dt$$

$$CS(X;\theta) = \frac{1}{2}\left(nc_s(\theta)\right)^2\frac{1-e^{-rT(X;\theta)}}{r} + e^{-rT(X;\theta)}WC(X_2(\theta);\theta)$$

or

$$CS(X;\theta) = \frac{1}{2r}\left(nc_s(\theta)\right)^2 + e^{-rT(X;\theta)}\left(WC(X_2(\theta);\theta) - \frac{1}{2r}\left(nc_s(\theta)\right)^2\right)$$

where $T(X;\theta)$ is the time needed for the stock to decrease from a value $X \in [X_2(\theta), X_{2,\infty}^{(\theta)}]$ to $X_2(\theta)$. We can determine $T(X;\theta)$ using

$$\dot{X} = \delta X - nc_s(\theta)$$

along with

$$X(T) = X_2(\theta)$$

and we have

$$e^{\delta T(X;\theta)} = \frac{X_2(\theta) - \frac{nc_s(\theta)}{\delta}}{X - \frac{nc_s(\theta)}{\delta}}$$

or

$$e^{-rT(X;\theta)} = \left(\frac{X_2(\theta) - \frac{nc_s(\theta)}{\delta}}{X - \frac{c_s(\theta)}{\delta}}\right)^{-\frac{r}{\delta}}.$$

We have $CS(X_2(\theta);\theta) - \frac{1}{2r}\left(nc_s(\theta)\right)^2 < 0$ and $T(X;\theta)$ and increasing function of $X$ therefore $CS(X;\theta)$ is an increasing function of $X$ for $X \in [X_2(\theta), X_{2,\infty}^{(\theta)}]$.

For $X \geq X_{2,\infty}^{(\theta)}$ we have $CS(X;\theta) = \frac{1}{2r}\left(nc_s(\theta)\right)^2$

For $X < X_1(\theta)$ we have $CS(X;\theta) = \left(\frac{X_1(\theta)}{X}\right)^{-\frac{r}{\delta}} CS(X_1(\theta);\theta)$. Indeed we have $CS(X;\theta) = e^{-r\tau(X;\theta)} CS(X_1(\theta);\theta)$ where $\tau(X;\theta)$ is the time needed for the stock to reach $X_1(\theta)$. This is determined using

$$\dot{X} = \delta X$$

along with

$$X(T) = X_1(\theta)$$

and we have

$$e^{\delta\tau(X;\theta)} = \frac{X_1(\theta)}{X}$$

or

$$e^{-r\tau(X;\theta)} = \left(\frac{X_1(\theta)}{X}\right)^{-\frac{r}{\delta}}.$$

Social welfare $SW(X;\theta)$ is therefore a non-decreasing function of $X$, being the sum of two non-decreasing functions of $X$.

We are now ready to determine the sign of $SW(X_1(0);\theta) - SW(X_1(0);0)$. We have

$$SW(X_1(0);\theta) - SW(X_1(0);0) = CS(X_1(0);\theta) + nV(X_1(0);\theta) - nV(X_1(0);0) - CS(X_1(0);0)$$

Using (19) and (20) we obtain after simplification

$$SW(X_2(\theta);\theta) - SW(X_2(\theta);0) = \frac{\theta n\left(4a\delta(-2\delta n + (n+1)r) - \theta\left(4\delta^2 n - (2\delta - r)(n-1)^2 r\right)\right)}{8\delta^2(n+1)^2 r} < 0$$

It can be shown that $SW(X;\theta) - SW(X;0)$ is a strictly increasing linear function of $X$ for $X \in [X_1(0), X_2(\theta)]$ with slope $\frac{\theta(n-1)(2\delta-r)}{4\delta}$. This implies that

$$SW(X;\theta) - SW(X;0) < 0 \text{ for all } X \in [X_1(0), X_2(\theta)].$$

On the other hand, at $X = X_{2,\infty}^{(\theta)}$, $SW(X;\theta) - SW(X;0) > 0$ because the steady-state output at $X_{2,\infty}^{(\theta)}$ is higher when firms are more motivated by status concern.

Continuity of $SW(X;\theta) - SW(X;0)$ with respect to $X$ ensures that there exists $\tilde{X} \in [X_2(\theta), X_{2,\infty}^{(\theta)})$ such $SW(X;\theta) - SW(X;0) = 0$.

**Appendix E**

To establish this result we first compute $X'_\beta$ and $X''_\beta$: they are the two positive solutions to

$$\phi_p(X;\beta) = \phi_p(X;0)$$

where $X'_\beta$ is the solution that belongs to the interval of stocks where both strategies are strictly increasing in $X$ whereas $X''_\beta$ belongs to the interval stocks where $\phi_p(X;\beta)$ is strictly increasing $X$ while $\phi_p(X;0)$ is constant and equal to $c_{sp}(0)$.

More precisely, $X'_\beta$ solves

$$(X - X_{1p}(\beta))\frac{c_{sp}(\beta)}{X_{2p}(\beta) - X_{1p}(\beta)} = (X - X_{1p}(0))\frac{c_{sp}(0)}{X_{2p}(0) - X_{1p}(0)}$$

which yields

$$X'_\beta = \frac{X_{1p}(\beta)\frac{c_{sp}(\beta)}{X_{2p}(\beta)-X_{1p}(\beta)} - X_{1p}(0)\frac{c_{sp}(0)}{X_{2p}(0)-X_{1p}(0)}}{\frac{c_{sp}(\beta)}{X_{2p}(\beta)-X_{1p}(\beta)} - \frac{c_{sp}(0)}{X_{2p}(0)-X_{1p}(0)}}$$

After substitution of $X_{1p}(\beta)$, $X_{2p}(\beta), X_{1p}(0)$ and $X_{2p}(\beta)$ it can be shown that

$$\frac{c_{sp}(\beta)}{X_{2p}(\beta) - X_{1p}(\beta)} = \frac{2\delta - r}{2n^2}\left(n + \frac{1}{1+\beta}\right)$$

and

$$X'_\beta = a\frac{(2n + n\beta + 1)\,2\delta - \left(2n + n\beta - n^2\beta - n^2 + 1\right)r}{\delta\,(2\delta - r)\,(n+1)\,(n\,(1+\beta)+1)}$$

As for $X''_\beta$, it is the unique solution to

$$(X - X_{1p}(\beta))\,\frac{c_{sp}(\beta)}{X_{2p}(\beta) - X_{1p}(\beta)} = c_{sp}(0) = \frac{a}{1+n}$$

After substitution of $X_{1p}(\beta)$ and $X_{2p}(\beta)$ we obtain

$$X''_\beta = \frac{\frac{a}{1+n}}{\frac{c_{sp}(\beta)}{X_{2p}(\beta)-X_{1p}(\beta)}} + X_{1p}(\beta)$$

or

$$X''_\beta = \frac{\frac{a}{1+n}}{\frac{2\delta-r}{2n^2}\left(n + \frac{1}{1+\beta}\right)} + \frac{a\left(2\delta - \left(1 + (1+\beta)^2\,n^2\right)r\right)}{\delta\,(1 + (1+\beta)\,n)^2\,(2\delta - r)}$$

We can now compute $\Delta$. After algebraic manipulations we obtain

$$\Delta = X''_\beta - X'_\beta = 2a\frac{n}{\delta}\frac{(\beta+1)}{(n+1)\,(n+n\beta+1)^2}H\,(\beta, n, \delta, r)$$

with $H\,(\beta, n, \delta, r)$ being defined by

$$H\,(\beta, n, \delta, r) = \frac{\left(2 - \left(n\,(1+\beta) - n^2\,(1+\beta)^2\right)\delta + (1 - n\,(1+\beta))\,r\right)}{2\delta - r}$$

Taking the derivative with respect to $r$ yields

$$\frac{\partial H\,(\beta, n, \delta, r)}{\partial r} = n\delta\frac{\beta+1}{(r-2\delta)^2}\,(n + n\beta - 3)$$

Therefore for $n \geq 3$ we have that $\frac{\partial\Delta}{\partial r} > 0$. An increase in the discount rate, i.e. as the long-run run becomes less valuable, the larger the interval of stocks for which we obtain a reversal of the standard impact of status concern expands. (This also holds for $n = 2$ and $\beta > \frac{1}{2}$; however for $n = 2$ and $\beta < \frac{1}{2}$, we have $\frac{\partial\Delta}{\partial r} < 0$.)

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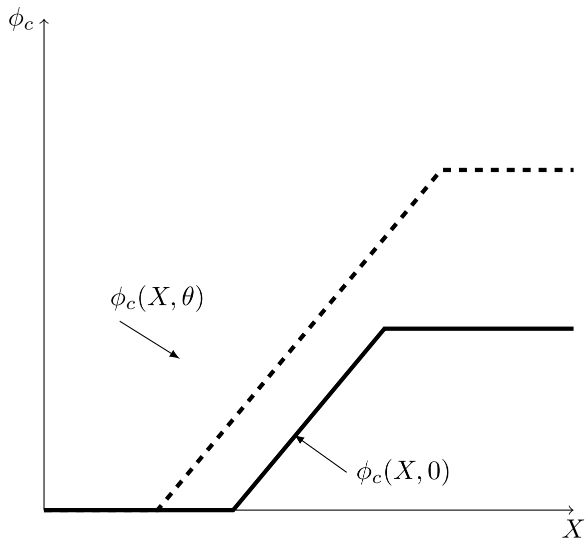


**Figure 1:** Social Status and Relative Consumption

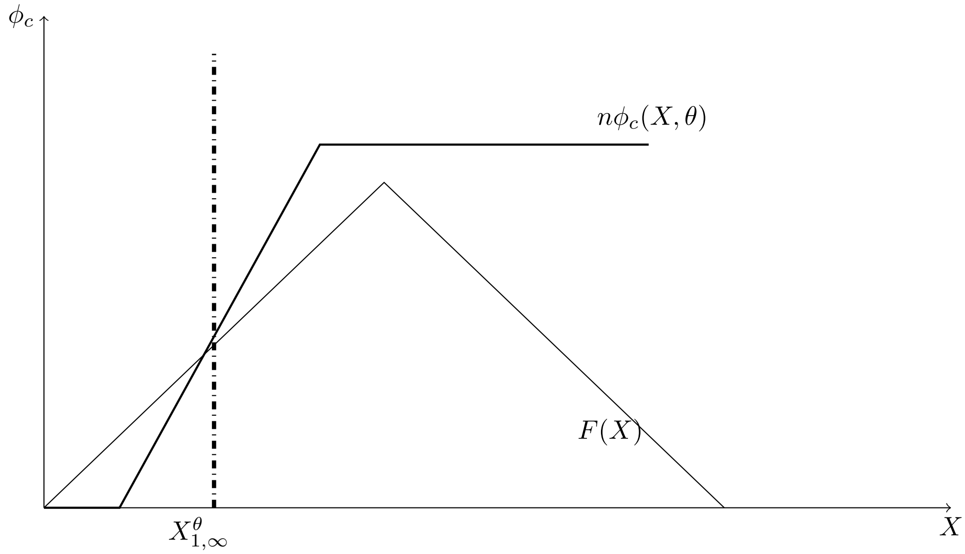


**Figure 2:** Social Status, Relative Output and Steady States - Small MSY

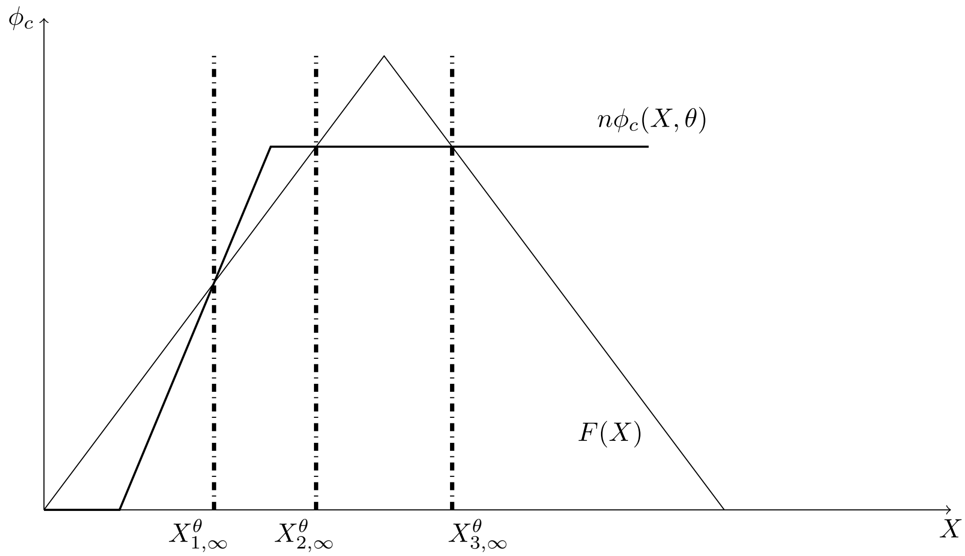


**Figure 3:** Social Status, Relative Output and Steady States - Large MSY

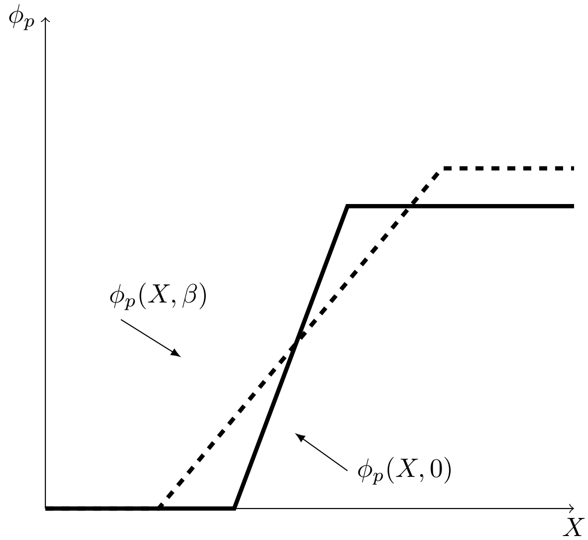


**Figure 4:** Social Status and Relative Profits

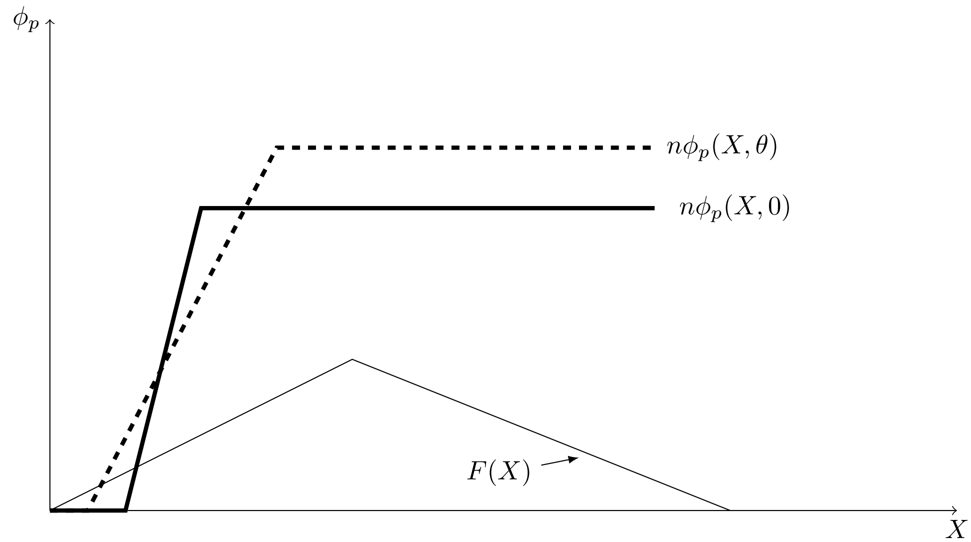


**Fig. 5A:** Social Status, Relative Profits and Steady States - Small MSY

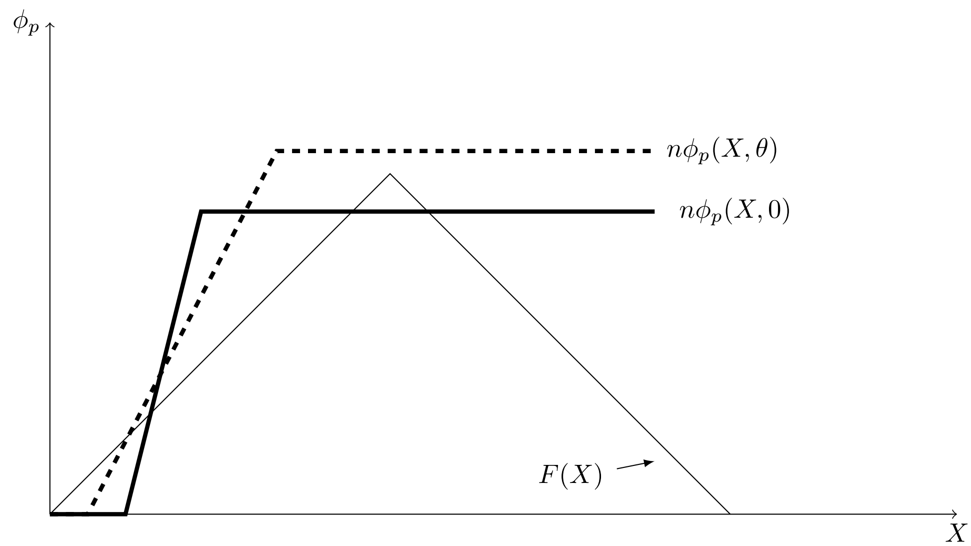


**Fig. 5B:** Social Status, Relative Profits and Steady States - Intermediate MSY

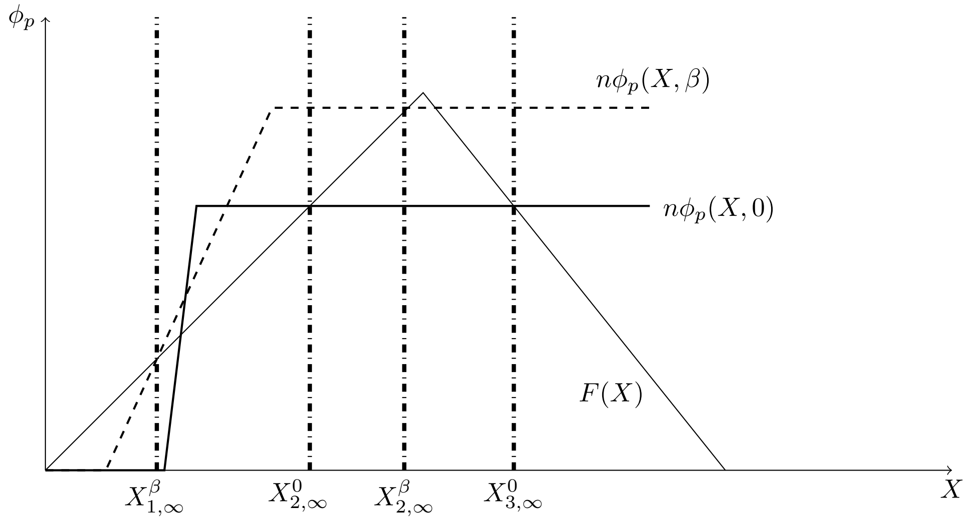


**Fig. 5C:** Social Status, Relative Profits and Steady States - Large MSY

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