Asymmetric Information May Protect the Commons:

The Welfare Benefits of Uninformed Regulators[*]

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Abstract

We examine an entry-deterrence model in the commons. We investigate in which contexts asymmetric information among firms becomes welfare improving, and in which settings an uninformed regulator may prefer to assess and disseminate information about the available stock among firms.

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1 Introduction

Governments are often actively engaged in assessing the scarcity of common pool resources in order to prevent overexploitation. This paper, however, suggests that uninformed regulators should not necessarily conduct such efforts, since a larger welfare may arise when firms exploiting the commons operate in a context of asymmetric information about the available stock.

This result is especially relevant in industries where the incumbent firm has access to more accurate information about the resource than the potential entrant. In this setting, the incumbent uses its exploitation to reveal or conceal information about the stock, and thus deter entry.[1] While this strategic exploitation might be welfare improving in certain contexts, it can become welfare reducing otherwise. In particular, when the environmental damage from exploiting the commons is relatively low, we show that a complete information context is welfare superior, regardless of the state of the stock. However, when such environmental damage is higher, maintaining an incomplete information structure yields a larger social welfare due to the incumbent's strategic behavior. Our results suggest, hence, that in an entry-deterrence context regulatory authorities do not need to closely monitor and publicize the stock of natural resources.

Several studies have analyzed the role of information in promoting the overexploitation of natural resources or, instead, reducing its appropriation below socially optimal levels; see Ostrom (1990), Mason and Polasky (1994), Polasky and Bin (2001), and Laurent-Lucchetti et al. (2011).[2] Unlike these articles, we examine an entry-deterrence game in which firms compete to exploit the same commons. In this context, firms underexploit the resource under certain conditions; as shown in Espinola-Arredondo and Munoz-Garcia (EM, 2011, 2013). However, after characterizing equilibrium results, they only compare appropriation levels under different information contexts. In this paper, we explicitly evaluate the welfare properties of incomplete information in the commons, which allows us to identify more precise policy recommendations, such as the acquisition and dissemination of information by uninformed regulators. The following section describes the model, section 3 analyzes the welfare arising when the stock is low or high; while section 4 discusses policy implications.

2 Model

Following EM (2011), consider a common pool resource, initially exploited by an incumbent (e.g., a fishery), threatened by a potential entrant. In the first stage, the incumbent observes the available stock in the commons, either high, θ_H, or low, θ_L, where $\theta_H > \theta_L$, but the entrant does not. Upon observing the level of the stock, the incumbent chooses a first-period appropriation, $x > 0$. The market is perfectly competitive and the price is normalized to one. The firm faces a cost function of $\frac{x^2}{\theta_K}$, where $K = \{H, L\}$, thus yielding first-period profits of $x - \frac{x^2}{\theta_K}$. At this point,

[1] For examples of fishing grounds behaving as prescribed by this equilibrium prediction, see Mason and Polasky (1994) and Espinola-Arredondo and Munoz-Garcia (2011).

[2] For a comprehensive review of the literature on common pool resources, see Faysee (2005).

the potential entrant observes the incumbent's first-period appropriation, and updates its beliefs about the available stock being high, $\mu(\theta_H|x) \in [0,1]$. As in similar entry-deterrence games, assume that entry is only profitable when the stock is high. If entry does not occur, the incumbent maintains its monopoly power, and chooses a second-period appropriation, $q > 0$, that maximizes its profits $q - \frac{q^2}{\theta_K-(1-\beta)x}$. Intuitively, the cost function is increasing and convex in second-period appropriation, q, decreasing in the regeneration rate of the resource, $\beta \in [0,1]$, and increasing in first-period appropriation, x.[3] If, instead, entry ensues, incumbent and entrant compete for the resource. In this setting, every firm $i = \{1,2\}$ simultaneously and independently selects a second-period appropriation level, $q_i > 0$, that maximizes $q_i - \frac{q_i(q_i+q_j)}{\theta_K-(1-\beta)x}$ for $j \neq i$, where firm i's costs are increasing in its opponent's appropriation, i.e., exploiting the resource becomes more difficult as the competitor increases its appropriation.

Finally, assume that the regulator's social welfare function in each period is $W \equiv \gamma CS + PS - ED$, where $CS \equiv \int_0^Q p(y)dy$ denotes consumer surplus, and $p(Q) = a - Q$ represents the inverse demand function where $Q \equiv q_i + q_j$; PS is the producer surplus from all firms exploiting the commons; and ED denotes the environmental damage (e.g., biodiversity loss) associated to the exploitation of the resource, which is convex in the aggregate appropriation level in each period, i.e., dx^2 in the first period and dQ^2 in the second period. In addition, $\gamma \in [0,1]$ is the share of appropriation that is sold domestically, while $d \in [0,1]$ indicates the severity of the environmental damage from appropriation. For simplicity, we assume no discounting of future payoffs.

3 Signaling in the commons

3.1 Low stocks

In a complete information setting, if the available stock is low, the entrant stays out. Under an incomplete information context, however, EM (2011, 2013) show that a separating equilibrium can be sustained in which the low-stock incumbent has incentives to underexploit the commons (relative to a complete information benchmark) in order to reveal its stock to potential entrants, thus preventing entry. The next lemma demonstrates that, while first-period appropriation is lower, the increase in second-period appropriation yields an overall increase in the exploitation of the resource.

Lemma 1. *When the available stock is low, first-period (second-period) appropriation is lower (higher, respectively) in the separating equilibrium (SE) than under complete information (CI) ,i.e., $x^{L,CI} > x^{L,SE}$ but $q^{L,CI} < q^{L,SE}$. Overall exploitation is larger in the separating equilibrium than under complete information, i.e., $x^{L,SE} + q^{L,SE} > x^{L,CI} + q^{L,CI}$, under all parameter values.*

This result suggests that incomplete information entails the emergence of three type of welfare effects (one positive, and two negative). Specifically, incomplete information produces: (1) an in-

[3] In addition, when the stock fully regenerates, $\beta = 1$, the same amount of stock is available in the first- and second-period game. In this context, the incumbent faces the same cost function in both periods.

crease in consumer surplus, since overall appropriation is larger; (2) a reduction in the incumbent's profits, given that the firm needs to under-exploit the commons to deter entry;[4] and (3) an increase in the environmental damage, which originates from a larger overall production in the separating equilibrium. For compactness, we hereafter refer to these welfare effects as (1)-(3). The next proposition identifies under which conditions the positive effect from a larger consumer surplus, in (1), dominates the two welfare losses, which emerge from lower profits, in (2), and larger environmental damages, in (3); ultimately yielding a welfare improvement.

Proposition 1. *When the available stock is low, social welfare is larger under incomplete than under complete information if and only if $\gamma > \overline{\gamma}$ (see appendix for $\overline{\gamma}$).*

Figure 1 depicts cutoff $\overline{\gamma}$,[5] thus generating two regions of $(\gamma, d)-$pairs: one in which the separating equilibrium is welfare improving (above cutoff $\overline{\gamma}$, in the shaded area), and another in which it is welfare reducing (below $\overline{\gamma}$).

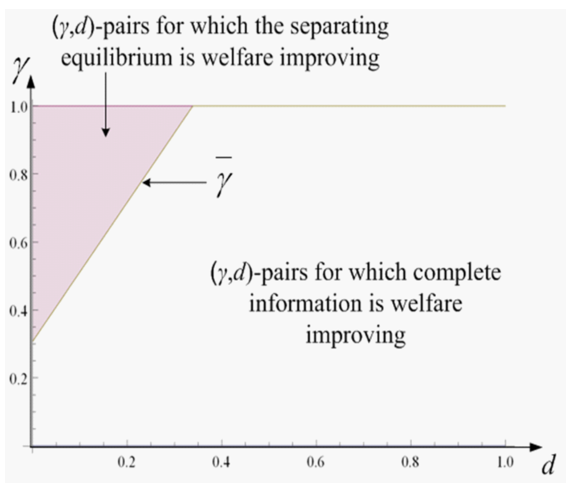

Figure 1. Welfare omparisons under θ_L.

Intuitively, when the exploitation of the commons does not entail environmental damages, i.e., $d = 0$ in the vertical axis, the separating equilibrium only produces welfare effects (1) and (2), but does not give rise to (3). In contrast, when all appropriation is sold overseas, $\gamma = 0$ along the horizontal axis, the introduction of incomplete information only yields the welfare losses in (2) and (3). Finally, when both γ and d are strictly positive, all welfare effects (1)-(3) are present, and the separating equilibrium becomes welfare improving if the welfare benefit from (1) is sufficiently large (high values of γ) and the welfare loss from (3) is relatively low (small values of d).[6]

[4] The incumbent maintains its monopoly power both under complete and incomplete information. However, deterring entry becomes more costly in the latter (where the firm needs to under-exploit the resource) than in the former (where the incumbent does not need to deviate from profit-maximizing appropriation levels).

[5] The figure considers stock levels $\theta_H = 10$ and $\theta_L = 5$, $a = 10$, and a regeneration rate of $\beta = \frac{6}{10}$. Other parameter values yield similar results, and can be provided by the authors upon request.

[6] In addition, cutoff $\overline{\gamma}$ is decreasing in θ_L, and in the regeneration rate, β. Hence, the region in which the separating

3.2 High stocks

Unlike a low available stock, a high stock attracts the potential entrant in a complete information setting. Under incomplete information, however, EM (2011) demonstrate that, under certain conditions, a pooling equilibrium emerges in which the high-stock incumbent strategically mimics the exploitation level of a low-stock firm in order to conceal information, and thus deter entry.[7] This suggests that appropriation levels are reduced (relative to complete information) both in the first period (when the incumbent underexploits the commons) and in the second period (since a single firm operates). The next lemma confirms this result.

Lemma 2. *When the available stock is high, first- and second-period appropriation is lower in the pooling equilibrium (PE) than under complete information, i.e.,* $x^{H,CI} > x^{H,PE}$ *and* $q^{H,CI} > q^{H,PE}$*. Overall exploitation is smaller in the pooling equilibrium than under complete information, i.e.,* $x^{H,PE} + q^{H,PE} < x^{H,CI} + q^{H,CI}$*, under all parameters.*

This lemma, hence, shows that the welfare effects of incomplete information in a high-stock commons are opposed to those in a low-stock resource. In particular, a reduction in overall appropriation yields a welfare loss (lower consumer surplus), but two welfare benefits (an increase in profits,[8] and a smaller environmental damage). The next proposition identifies under which parameter conditions the welfare benefits dominate the losses, ultimately leading to a welfare improvement.

Proposition 2. *When the available stock is high, social welfare is larger under incomplete than under complete information, for all* $\gamma < \widehat{\gamma}$ *(see appendix for* $\widehat{\gamma}$*).*

Figure 2 depicts cutoff $\widehat{\gamma}$, thus dividing the set of $(\gamma, d)-$pairs into two regions: that in which incomplete information is welfare improving, i.e., $\gamma < \widehat{\gamma}$ in the shaded area, and that in which it is welfare reducing.[9] Importantly, when $d = 0$, only two welfare effects arise: a lower consumer surplus and an increase in profits. In contrast, when $\gamma = 0$, the only two welfare effects are actually positive: an increase in profits and a reduction in the environmental damage from appropriation; ultimately yielding an unambiguous welfare improvement. Finally, when both γ and d are positive, all welfare effects are present, and the two positive effects dominate the negative effect if d is sufficiently high.

equilibrium is welfare improving (above the diagonal cutoff), expands as θ_L increases. Intuitively, as the stock becomes more abundant, the incumbent's incentives to deter entry increase, thus leading the firm to more significantly decrease its first-period appropriation. In this setting, the negative welfare effects embodied in (1) and (3) are smaller, thus allowing for incomplete information to yield a welfare improvement under larger parameter conditions. A similar argument applies to the regeneration rate, β, since a larger value of β indicates a more profitable commons that the incumbent seeks to protect.

[7] Specifically, the high-stock incumbent has incentives to practice the entry-deterring strategies prescribed in the pooling equilibrium when the low-stock it seeks to mimic is not significantly lower than its high stock, i.e., θ_L satisfies $\theta_H > \theta_L > \overline{\theta_L}$, where $\overline{\theta_L} \equiv \theta_H - \frac{\sqrt{5}\sqrt{(3+\beta)^2[85+\beta(46+13\beta)]\theta_H^2}}{9(3+\beta)^2}$.

[8] Otherwise, the high-stock incumbent would not have incentives to conceal its type from potential entrants, and would thus behave as under complete information.

[9] For consistency, the figure also considers $\theta_H = 10$ and $\theta_L = 5$, $a = 10$, and a regeneration rate of $\beta = \frac{6}{10}$.

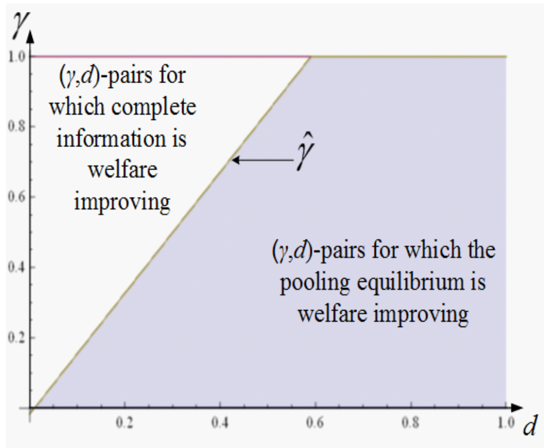

Figure 2. Welfare comparisons under θ_H.

4 Discussion

Regulators are often as uninformed about the available stock as potential entrants, since they usually have access to similar technologies. Despite the regulator's lack of information, our findings suggest precise policy implications. In particular, figure 3a superimposes cutoffs $\overline{\gamma}$ and $\widehat{\gamma}$, and indicates that, when $(\gamma, d)-$pairs take intermediate values (i.e., $\overline{\gamma} > \gamma > \widehat{\gamma}$ in the shaded region II) regulatory authorities could anticipate that firms' strategic exploitation under incomplete information yields an unambiguous welfare loss, which emerges *regardless* of the value of the stock. This welfare loss could only be prevented if regulatory authorities change the structure of the game to one of complete information by, for instance, incurring the cost of researching the available stock, and subsequently publicizing it on different media outlets. If these costs are smaller than the welfare gain associated with disseminating this information, the regulator would have incentives to acquire and distribute information among firms.

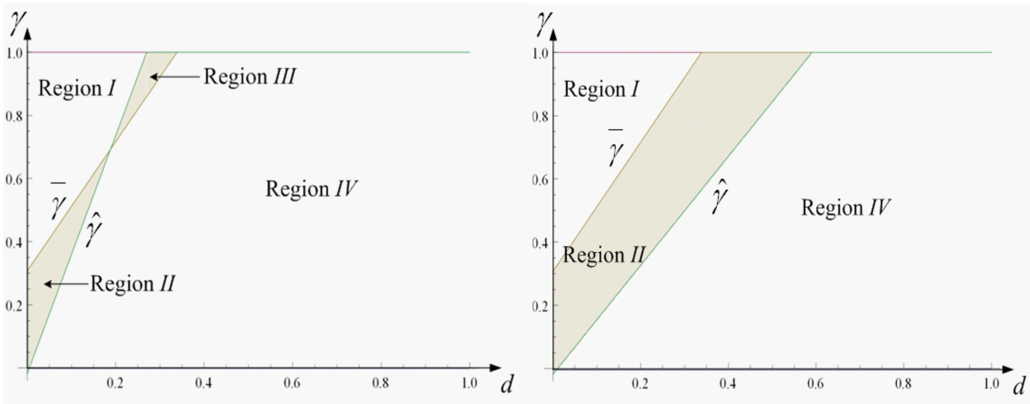

Fig. 3a. Combined comparisons, $\beta = 0.2$. Fig. 3b. Combined comparisons, $\beta = 0.6$.

In region III, instead, the presence of incomplete information yields a welfare gain, *irrespective* of the stock. In particular, if the stock is low, the separating equilibrium arises and the gains in consumer surplus, thanks to a high γ, are relatively large. Likewise, if the stock is high, the pooling equilibrium emerges and, hence, the environmental damage is small. These welfare gains are sufficiently large to result in an overall welfare improvement relative to complete information. As a consequence, the uninformed regulator would have no incentives to acquire information about the state of the stock. Finally, in region I (IV), incomplete information would entail a welfare improvement only if the available stock is low (high, respectively). Figure 3b depicts the case in which the regeneration rate is higher. In this case, region III is absent, while region II (where complete information is welfare improving) expands.[10] Since region III is present only when β is sufficiently low (as in figure 3a), our results suggest that asymmetric information tends to be welfare improving when output is mainly sold domestically (high γ) and for slowly-renewable resources (low β).

Our model could be extended to contexts in which regulators have access to more information about the stock than potential entrants, which might occur if they are small firms with inferior technologies. In this case, the regulator's decision on whether to publicize the available stock would become an additional signal that the entrant could use to infer the stock's type.

[10] Intuitively, cutoff $\widehat{\gamma}$ pivots downwards since appropriation increases in the regeneration rate. As a result, environmental damage is significant, thus shrinking the region in which the pooling equilibrium is welfare improving.

5 Appendix

5.1 *Proof of Lemma 1*

As shown in EM (2013), under CI, the low-stock incumbent appropriates $x^{L,CI} = \frac{\theta_L[4-(1-\beta)]}{8}$ in the first period, and $q^{L,CI} = \frac{\theta_L[5+\beta(4-(2-\beta))]}{16}$ in the second period, thus implying an overall appropriation of $x^{L,CI} + q^{L,CI} = \frac{\theta_L\left[4(3+\beta)-\left(1-\beta^2\right)\right]}{16}$. Under incomplete information, a SE can be sustained in which the firm selects $x^{L,SE} = \frac{9[4-(1-\beta)]\theta_H+\sqrt{5}\sqrt{[72(1+\beta)+13(\beta-1)^2]\theta_H^2}}{72}$ in the first period, and

$$q^{L,SE} = \frac{9\left[5+\beta(4-(2-\beta))\right]\theta_H - \sqrt{5}(1-\beta)\sqrt{\left[72(1+\beta)+13(\beta-1)^2\right]\theta_H^2}}{144}$$

in the second period. This SE can be sustained if $\theta_L < \theta_H + \frac{\sqrt{5}\sqrt{[85+\beta(46+13\beta)]\theta_H^2}}{9(3+\beta)}$. However, such condition on θ_L holds for all parameter values, since $\theta_L < \theta_H$ by definition.

We can now solve for c_L in $\left(x^{L,CI}+q^{L,CI}\right) - \left(x^{L,SE}+q^{L,SE}\right)$ to obtain that $x^{L,CI}+q^{L,CI} < x^{L,SE}+q^{L,SE}$ for all $\theta_L < \widehat{\theta_L}$, where

$$\widehat{\theta_L} \equiv \frac{9\left[11+\beta(4+\beta)\theta_H\right] + \sqrt{5}(1+\beta)\sqrt{\left[85+\beta(46+13\beta)\right]\theta_H^2}}{9[11+\beta(4+\beta)]}$$

However, $\widehat{\theta_L} > \theta_H$ holds for all parameter values, thus implying that $x^{L,CI}+q^{L,CI} < x^{L,SE}+q^{L,SE}$ is satisfied for all $\theta_L < \theta_H$. ■

5.2 *Proof of Proposition 1*

Under CI, social welfare is

$$W^{L,CI} \equiv \frac{\theta_L\left[4\left[25+\beta(6+\beta)\right]+8(a-1)\left[11+\beta(4+\beta)\right]\gamma - \left[4(3+\beta)^2+(5+\beta(2+\beta))^2 d\theta_L\right]\right]}{256}.$$

Under the SE, consumer surplus is $CS^{L,SE} \equiv \frac{\gamma}{2}(a-1)x^{L,SE} + \frac{\gamma}{2}(a-1)q^{L,SE}$ since $p=1$; the producer surplus (given that a single firm operates in both periods) is $PS^{L,SE} \equiv \left(x^{L,SE} - \frac{\left(x^{L,SE}\right)^2}{\theta_L}\right) + \left(q^{L,SE} - \frac{\left(q^{L,SE}\right)^2}{\theta_L-(1-\beta)x^{L,SE}}\right)$; and the environmental damage is $ED^{L,SE} \equiv d\left(x^{L,SE}\right)^2 + d\left(q^{L,SE}\right)^2$. Hence, the social welfare in the SE is $W^{L,SE} \equiv CS^{L,SE} + PS^{L,SE} - ED^{L,SE}$. Comparing $W^{L,CI}$ and $W^{L,SE}$, we obtain that $W^{L,CI} \leq W^{L,SE}$ if and only if $\gamma \geq \overline{\gamma}(\theta_H, \theta_L, a, \beta)$ which, for $\theta_H = 10$, $\theta_L = 5$, $a = 10$, and $\beta = \frac{6}{10}$, yields $\overline{\gamma} = 0.31 + 2.04d$. ■

5.3 *Proof of Lemma 2*

As shown in EM (2013), under CI, the high-stock incumbent appropriates $x^{H,CI} = \frac{\theta_H[9-(1-\beta)]}{18}$ in the first period, and $q_i^{H,CI} = \frac{\theta_L[10+\beta(9-(2-\beta))]}{54}$ in the second period (where $q_j^{H,CI} = q_i^{H,CI}$ since firms are symmetric). Overall appropriation is $x^{H,CI} + \left(q_i^{H,CI} + q_j^{H,CI}\right) = \frac{\theta_H[44+\beta(18-(1-2\beta))]}{54}$. Under incomplete information, a PE can be supported in which the firm selects $x^{H,PE} = \frac{\theta_L[4-(1-\beta)]}{8}$ in the first period, and $q^{H,PE} = \frac{8\theta_H - \theta_L(1-\beta)[4-(1-\beta)]}{16}$ in the second period, thus yielding $x^{H,PE} + q^{H,PE} = \frac{8\theta_H + \theta_L(1+\beta)[4-(1-\beta)]}{16}$. We can now solve for θ_L in $\left(x^{H,CI} + q_i^{H,CI} + q_j^{H,CI}\right) - \left(x^{H,PE} + q^{H,PE}\right)$ to obtain that $x^{H,CI} + q_i^{H,CI} + q_j^{H,CI} > x^{H,PE} + q^{H,PE}$ for all $\theta_L < \widetilde{\theta_L}$, where $\widetilde{\theta_L} \equiv \frac{8\theta_H[17+\beta(17+2\beta)]}{27(1+\beta)(3+\beta)}$. However, $\widetilde{\theta_L} > \theta_H$ holds for all parameter values, thus implying that $\theta_L < \widetilde{\theta_L}$ is satisfied for all $\theta_L < \theta_H$. ■

5.4 *Proof of Proposition 2*

Under CI, social welfare is

$$W^{H,CI} \equiv \frac{\theta_H \left[27\left[40 + \beta(10+\beta) + 27(a-1)\left(44 + \beta(17+2\beta)\right)\gamma - \left(4(2+\beta)^2(5+\beta)^2 + 9(8+\beta)^2\right) d\theta_H\right]\right]}{2916}.$$

Under the PE, consumer surplus is $CS^{H,PE} \equiv \frac{\gamma}{2}(a-1)x^{H,PE} + \frac{\gamma}{2}(a-1)q^{H,PE}$; the producer surplus (since a single firm operates in both periods) is

$$PS^{H,PE} \equiv \left(x^{H,PE} - \frac{\left(x^{H,PE}\right)^2}{\theta_H}\right) + \left(q^{H,PE} - \frac{\left(q^{H,PE}\right)^2}{\theta_H - (1-\beta)\left(x^{H,PE}\right)}\right)$$

and the environmental damage is $ED^{H,PE} \equiv d\left(x^{H,PE}\right)^2 + d\left(q^{H,PE}\right)^2$. Hence, the social welfare in the PE is $W^{H,PE} \equiv CS^{H,PE} + PS^{H,PE} - ED^{H,PE}$. Comparing $W^{H,CI}$ and $W^{H,PE}$, we obtain that $W^{H,CI} \leq W^{H,PE}$ if and only if $\gamma \leq \widehat{\gamma}(\theta_H, \theta_L, a, \beta)$ which, for $\theta_H = 10$, $\theta_L = 5$, $a = 10$, and $\beta = \frac{6}{10}$, yields $\widehat{\gamma} = 1.72d - 0.02$. ■

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