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Strategic exploitation of a common resource under environmental risk

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ABSTRACT

We study the effect of environmental risk on the extraction of a common resource. Using a dynamic and non-cooperative game in which an environmental event impacts the renewability and the quality of the resource, we show that the anticipation of such an event has an ambiguous effect on extraction and the tragedy of the commons. A risk of a reduction in the renewability induces the agents to extract less today while a risk of a deterioration in the quality has the opposite effect. Moreover, when environmental risk induces conservation, the tragedy of the commons is worsened.

1. Introduction

Natural common resources are susceptible to increasing environmental risks as reported in recent scientific studies. The most common prediction is a widespread reduction in the renewability (i.e., the future quantity) of the stock of natural resources. Declining fish stocks (Backlund et al., 2008); a decrease in global water availability (IPPC, 2007); an overall decline in crop yields for global temperature increases above 3 °C (IPPC, 2007); and a decrease in growth rates of tropical forests (Hopkin, 2007) are just a few examples. There is also scientific evidence regarding the negative effect of climate changes on the quality of natural resources. The US Department of Agriculture reports that an increase in extreme events brought on by climate changes, such as more frequent flooding, will reduce water quality (Backlund et al., 2008).[1]

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[1] Additionally, if we consider the resource at the aggregate level, then a decrease in the variety of species can be interpreted as a decrease in quality. Such a reduction in variety has the potential to be widespread as 30% of species are at an increasing risk of extinction (Kerr, 2007).

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Complementary to the scientific research, there exists a large literature in economics that asks how economic behavior is altered in anticipation of events that have detrimental effects on natural resources.[2] While many papers have found conservative behavior in the context of single-agent dynamic models, less is known about the link between conservative behavior and the tragedy of the commons. Specifically, there remains the question of whether the intensity of conservation differs in the non-cooperative outcome and the social planner's solution and if so, what the effect is on the tragedy of the commons.[3]

It is the purpose of this paper to consider whether the tragedy of the commons is reduced or exacerbated in the presence of environmental risk. To that end, we embed environmental risk in a dynamic and non-cooperative extraction game à la Levhari and Mirman (1980) and show that strategic interactions are key in explaining the effect of environmental risk on the tragedy of the commons. We focus on two effects of environmental risk consistent with the scientific evidence exposed above: renewability and quality. We consider a purely exogenous risk, i.e., the exploitation of a lone resource has a relatively small effect on regional or global environmental risk.[4] This is in contrast to a strand of the literature on (single-agent) optimal control which considers the problem of resource management under uncertainty when the agent can reduce the likelihood of the environmental risk (Clarke and Reed, 1994; Tsur and Zemel, 1995, 1996, 1998). Specifically, Tsur and Zemel (1995) study the management of groundwater resources at risk of a permanent and catastrophic event (ceasing exploitation activity).[5] Optimal exploitation is also studied in the context of managing the level of pollution in the case of environmental events (Clarke and Reed, 1994; Tsur and Zemel, 1996, 1998).[6] In all these cases, conservation can occur to prevent or reduce the likelihood of such events. In contrast, by focusing on a completely exogenous event, the change in behavior is solely due to reducing exposure to risk (instead of altering it).[7] Hence, we are able to provide results about the pure effect of environmental risk, thereby abstracting from any manipulation by the agents.[8]

We first show that when the environment becomes riskier, harvesting behavior is altered in order to reduce exposure to risk.[9] On the one hand, if environmental changes lead only to a lower renewability, agents reduce their exposure to this type of risk by harvesting less. The substitution toward future harvesting (and, thus, consumption) is due to precautionary motives since *saving more* allows one to compensate for a possibly less renewable resource and less future availability of the stock. On the other hand, if environmental changes lead only to lower quality, then agents reduce their exposure to risk by harvesting and consuming more in the present so as to face less risk in terms of future utility flows. When both quality and renewability are at risk of being deteriorated, the direction of the effect depends on the relative strength of the two effects. For instance, if the deterioration in quality is small compared to the negative change in renewability, then agents reduce their exposure to risk by harvesting less. In that case, precautionary motives dominate over concerns for lower future (per-unit) utility flows.

In view of our results, the reason for a change in behavior due to environmental risk is solely motivated by a reduction in the exposure to risk (and not manipulation of likelihood of risk as discussed above). In that sense, our framework is close to Lafforgue (2005), which provides such an analysis in the context of a single-agent optimal control problem of resource extraction when there is amenity value for the exploited stock. The effect of uncertainty is shown to be ambiguous as well, and can lead to conservation. However, the overall effect depends on the size of uncertainty and not on the type of uncertainty, as in our paper (i.e., quality vs. renewability uncertainty).

After explaining how different types of risk affect harvesting, we turn to the tragedy of the commons. We show that when environmental risk induces conservation (i.e., when the risk of less renewability is more important than the risk of quality deterioration), the presence of the risk leads to a stronger decrease in present harvesting under social planning than in the non-cooperative game. Hence, the ratio between aggregate harvesting in the Cournot–Nash outcome and the socially optimal level of harvesting is increased, which makes the tragedy of the commons worse. Although agents choose to harvest less, they do not internalize the risk that too much extraction creates for others, and, thus, decrease their own extraction too little. The social planner, on the other hand, internalizes this effect and decreases harvesting more.

[2] See among others: Reed (1993), Clarke and Reed (1994), Tsur and Zemel (1995, 1996, 1998), Lafforgue (2005), Alvarez and Koskela (2006), Mitra and Roy (2006), and Polasky et al. (2011).

[3] The issue of whether increased uncertainty leads to more or less conservation has also been studied in the context of technology adoption. For instance, Just et al. (2005) considers the adoption of an existing backstop technology in problems of exhaustible resources when the discovery of superior technologies is anticipated. Delay in adopting the backstop technology would cause the resource to be depleted more rapidly.

[4] Exogenous uncertainty has also been studied extensively in models of resource extraction under ownership risk or weak property rights (Long, 1975; Bohn and Deacon, 2000; Laurent-Lucchetti and Santugini, 2012).

[5] In that vein, see Aflaki (2010) for a recent working paper regarding the effect of uncertainty on the tragedy of the commons in a non-dynamic context. In Aflaki (2010), individuals have an effect on the likelihood of the risk, in the sense that too much exploitation destroys the resource.

[6] Clarke and Reed (1994) consider the case in which the likelihood of the environmental change depends on the level of pollution, while Tsur and Zemel (1996, 1998) assume that the occurrence of the event depends on the pollution history.

[7] See also Polasky et al. (2011) for a recent study that combines the case of catastrophic stock collapse with changes in the system dynamics (as in our paper) in the context of a single-agent problem. Conservative behavior prevails whether the risk is exogenous or endogenous.

[8] The effect of exogenous uncertainty (not necessarily related to environmental risk) has been studied in single-agent dynamic problems (Mirman and Spulber, 1984; Feliz, 1993; Epstein, 1996; Mitra and Roy, 2006), as well as dynamic games with strategic behavior (Amir, 1996; Laukkanen, 2003; Antoniadou et al., 2007; Wang and Ewald, 2010). In these studies, the evolution of the stock depends on random shocks, while, in our approach, the source of uncertainty is the timing of an environmental event that leads to permanent changes in the characteristics of the natural resource.

[9] See Alvarez and Koskela (2006) and Reed (1993) for the issue of risk exposure and risk aversion in the context of forest management.