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Index Insurance and Common Property Pastures

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Abstract

This paper presents a theoretical model to investigate the potential environmental consequences of weather index based insurance, a tool for mitigating weather risk that is gaining momentum in developing countries. We model potential effects of index insurance for pastoralists on animal stocking decisions and the resulting effects on common property resource quality. We find that although this proposed financial tool has the potential of significantly enhancing the welfare of pastoralists by enhancing expected payoffs and reducing the exit of pastoralists, under certain conditions the insurance can worsen overstocking problems in low rainfall states of nature. In these cases, the insurance has an unintended negative effect on pasture quality that can undermine the long run sustainability of the common pool resource. Model extensions show that low error seasonal climate forecasts and/or reduction in ex-post stock readjustment costs arising from market imperfections can help in mitigating this potential negative effect.

Keywords: Index Insurance, Pasture, Common Property
JEL Classification: G2, O13, P14

1 Introduction

Rainfall uncertainty has always been a serious challenge for pastoralism, a livelihood associated with extreme poverty in many parts of the developing world. This poverty is driven by factors such as seasonal climate risk, missing credit & insurance markets, limited technological advancements and inefficient property rights structures[1]. Attempts are being made to help the pastoralists to deal with the climate risk and improve the returns from animals to enhance welfare. 'Index insurance' is one such financial tool. 'Index insurance', based on weather indicators like rainfall or satellite based greenness indices, is a relatively new risk mitigation tool that has been introduced for crop farmers in developing countries including India (Gine, et al, 2007; Cole et al, 2007), Malawi (Osgood et al, 2007). The rising popularity of this insurance amongst crop farmers has generated demand for its application for pastoralists in several developing countries. Pilot studies of index insurance for livestock are being carried out in Mongolia (Mahul and Skees, 2006) and Kenya (Patt et al, 2008). While the existing research has focused on insurance uptake and appropriate design and implementation of the insurance, we analyze the potential environmental effect of the insurance through a model of the relationship between index insurance and common property resources.

The index insurance aims to reduce weather risk while mitigating the moral hazard problem associated with the traditional yield based insurances, as the index insurance payoffs are triggered by weather indicators like rainfall, that the clients cannot manipulate (Turvey, 2001; Barnett, 2004; Barnett, Barrett & Skees, 2006). The focus of policy makers and research has been concentrated on the uptake and appropriate design

[1] See Fratkin (1997) for an overview of the governance challenges for pastoralism in different developing countries. McPeak & Barrett (2001) present the varied risks and the associated poverty traps faced by the East African pastoralists.

of the insurance contracts. One aspect of particular concern in the literature is basis risk, which occurs when the insurance the index that acts as a trigger for insurance payoff (weather indicator or regional herd mortality) is not well correlated with individual risks or losses (Kalavakonda & Mahul, 2005). Studies also address factors affecting the adoption rates and scalability issues (Cole et al, 2007; Gine et al, 2007). None of these studies have analyzed any potential long run environmental implications of this financial tool.

Since the objective of index insurance is to mitigate weather risk, at a first glance, it has the potential to be an unambiguously beneficial tool for welfare enhancement of agriculturalists. Yet like any other tool, it can have unintended and undesired side effects. Reduction in weather risk can significantly alter the production decisions of pastoralists for which the rural natural resources like water and pasture are used as inputs. These resources often fall under open access or common property regime in developing countries and contribute to the sustenance of large number of rural livelihoods. Hence if the insurance changes the incentives of the pastoralists in a manner that leads to increased depletion of these resources, then there can be serious consequences for the rural communities. The case of dissemination of climate forecast information for Peruvian fishermen (Pfaff et al, 1999) demonstrates that weather forecast information, a risk mitigation tool, actually hurt the poorest fishermen due to imperfect distribution of the information, which the policymakers did not anticipate. Hence it is important to analyze if there is any potential negative effect of introducing index insurance on the rural environment and if so can the policymakers adopt additional precautionary tools to mitigate problems. Since the sustainability of rural pastoral communities depend on the common property resource, we present a stylized theoretical model to represent potential impacts of index insurance on pasture quality. We analyze the potential environmental impact of index insurance by comparing the animal stocking decision of pastoralists in the absence and presence of the insurance and the resulting effect on pasture quality. We focus on the case of common property pasture with a given number of users, a widely observed property rights regime for pastures in developing countries[2].

Our model depicts that in the absence of insurance, ex-ante animal stocking decision, with the objective of maximizing expected returns, results in suboptimal returns as well as over-stocking of animals relative to the optimal for low rainfall state of nature. This resonates well with the prevalent view in the literature. We find that the index insurance can benefit the pastoralists by enhancing their average payoffs and limiting drop-outs, however it does not help in addressing the problem of overstocking relative to the optimal in bad states of nature and can worsen the problem under certain model conditions. The poorest risk-averse pastoralists, constrained by the need to assure a minimum return in order to meet their basic needs in low rainfall states, face the most adverse situation, forgoing higher expected returns in order sustain themselves in bad states of nature. This process, although costly to the pastoralist, has the side effect of reducing the numbers of animals stocked, which helps the pasture in bad years when the pasture is most vulnerable. However in the presence of the insurance, the insurance

[2] Muller et al. (2006) is the only study that has analyzed the potential impact of index insurance on pastures. They present a detailed simulation model for a privately managed animal farm and show that with the introduction of weather based insurance, the pasture users with high discount rates and risk aversion would have less or no incentive to adopt the risk reducing practices they would have adopted in the absence of insurance in order to reduce their income variability, like leaving certain segments of the pastures away from grazing in good years that can act as buffers in bad years. Thus index insurance can have an undesired adverse effect on the pastures in bad years. It implies that even with the most efficient private property regime in place, index insurance can negatively affect the pasture in bad years. In the light of this finding, it is likely that the negative effect of index insurance on a pasture under less efficient regimes like open access or common property regime can be more severe.

payoff in bad state of nature helps the pastoralist to reduce or even eliminate the need for ensuring a minimum return in bad state of nature and thereby facilitates higher stocking decisions that can enhance the expected payoff in the short run. However it may undo the benefits to the environmental resource, removing an albeit costly practice to pastoralists but perhaps important check on the overutilization in bad years, leading to degraded resources in the longer term. Further analysis indicates that provision of low-error weather forecast at the ex-ante stocking decision stage and/or reduction in ex-post stock readjustment cost which arise due to market imperfections like limited and infrequent access to market, high transportation cost, price volatility, can help in mitigating the potential negative impact of the index insurance and allow the pastoralists reap the benefits in a sustainable way.

The rest of the paper is organized as follows. Section 2 lays out the model setup, section 3 analyzes the potential impact of index insurance, section 4 suggests some tools for mitigating the negative impact of the insurance and section 5 concludes.

2 Model

Our model for analyzing the impact of index insurance on pasture quality relies on the following assumptions.

Assumption 1. There is a common property pasture, which N homogeneous users can use for grazing animals.

This type of informal regulation of the number of users who can access a common property resource is widely prevalent in rural areas of developing countries. Common property resources can in principle be efficiently managed to obtain the optimal outcome of profit maximization, but it can also lead to inefficient outcome of rent dissipation depending upon the informal regulations and agent characteristics. We assume that the objective of homogenous group in our model is to maximize their net revenue from the pasture. Hence it represents the case of an efficiently managed common property. If we relaxed the assumption of homogenous users or assume that N tends to infinity, then we can get substantial rent dissipation or the classic open access case of complete rent dissipation. It is worth noting that even if the pastoralists optimize their year to year returns, this 'common property' regime still has the basic incentive problem of non-ownership i.e. the pastoralists do not own the pasture land and thus cannot sell the land in case of emergency, which limits their incentive to optimize the long run pasture returns. Because of the non-ownership of land their decisions are myopic in nature. Hence a single period optimization analysis can capture the essence of the problem.

Assumption 2. There are two discrete states of nature based on rainfall. A good and bad state correspond to high and low rainfall respectively. The rainfall outcome is determined stochastically by nature. $\alpha = p\ (R \leq R^*)$ is the probability of bad state, where R denotes actual rainfall and R^* denotes the threshold level of rainfall that demarcates the good and bad state of nature. We assume that all the pastoralists have a common prior about α.

Assumption 3. A pasture user is completely dependent on the revenue from animals for sustenance i.e. the pasture users are full time pastoralists without any additional source of income.

Assumption 4. The decision making process for a pastoralist involves three different stages.

Stage 1. At the beginning of each season, pasture user '*i*' makes an ex-ante decision to stock x_i animals such that in the event of a low rainfall outcome the stock can yield a net-revenue of at least $\overline{Y}$. Note that $\overline{Y}$ represents loan repayment and/or consumption requirement[3].

Stage 2. After the stocking decision is made, the nature reveals itself in form of a good (high rain) or bad (low rain) state.

Stage 3. Final payoffs are determined based on the end of season output[4].

A pastoralist makes an ex-ante stocking decision subject to a constraint that represents the need to meet a minimum amount of net return in the event of a bad draw of nature. We analyze this constrained optimization problem because meeting the subsistence survival needs, especially in the bad states of nature, is the main concern for poor pastoralists in most of the developing parts of the world. With the above set of assumptions, pastoralist '*i*' makes the stocking decision x_i based on the following optimization problem:

(1) $$\underset{x_i}{Max}\, \pi_i = [\alpha.p_L.f(x_i, N, G_L) + (1-\alpha).p_H.f(x_i, N, G_H)] - p_0.x_i$$

s.t. $$p_L.f(x_i, N, G_L) - p_0.x_i \geq \overline{Y}$$

where,

α is the probability of bad outcome

x_i is the number of animals of user '*i*'

N is the number of homogeneous pasture users

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[3] The constraint represented by $\overline{Y}$ is also indicator of risk aversion of the pastoralists as preference for assuring $\overline{Y}$ in bad state over an expected payoff of $\overline{Y}$ which may not assure $\overline{Y}$ in bad state (and assuring $\overline{Y}$ in bad state even at the cost of forgoing higher expected payoffs) represents a risk-averse behavior.

[4] We assume that there is no opportunity of intermediate stock readjustment. We will discuss this issue in section 4.

p_0 is the stocking cost per animal

$f(.)$ is the production function

p_L & p_H are the selling price per unit of output in bad and good state of nature respectively such that $p_L < p_H$

G_L & G_H are the measures of vegetation (forage) in the pasture in bad and good states respectively such that $G_L < G_H$

We assume the production function to have the following features:

i) $\frac{\partial f}{\partial N} < 0$ implies that increase in the size of the pasture user pool dampens the production for an individual pastoralist.

ii) $\frac{\partial f}{\partial x_i} > 0$ & $\frac{\partial^2 f}{\partial x_i^2} < 0$ imply a concave production function.

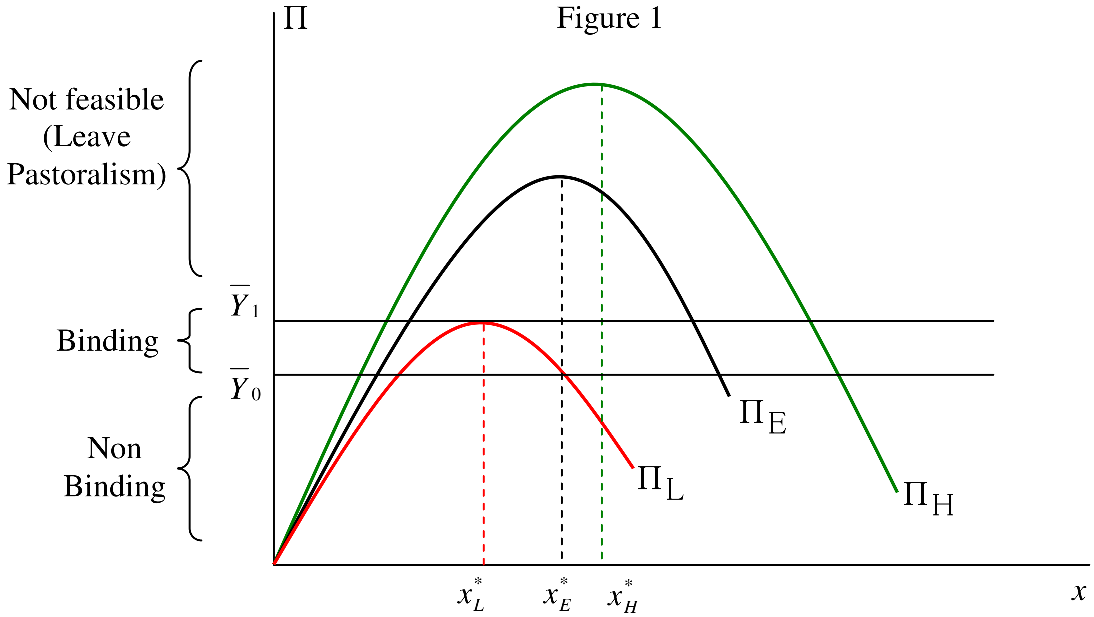
iii) $\left|\frac{\partial f}{\partial x_i}\right|_{G_H} > \left|\frac{\partial f}{\partial x_i}\right|_{G_L}$ & $\left|\frac{\partial^2 f}{\partial x_i^2}\right|_{G_H} < \left|\frac{\partial^2 f}{\partial x_i^2}\right|_{G_L}$ imply that the marginal productivity is lower and it declines at a faster rate in low rainfall state of nature relative to high rainfall state.

The derivations of the Kuhn Tucker conditions are presented in the appendix. The optimization exercise reveals that there are two feasible outcomes. One corresponds to the case of binding income constraint and the other corresponds to the case of non-binding income constraint. The rest of the cases are not feasible.

We can also interpret the mathematical results derived from the Kuhn Tucker conditions in the appendix using Figure 1, which depicts the three possible scenarios. Note that Π denotes the net-revenue function and x denotes animal stock. Subscripts L and H represent low rainfall (bad) and high rainfall (good) states of nature. Subscript E represents the expectation.

(i) *Non-binding income constraint*. If the income constraint is not binding, $\overline{Y} \leq \overline{Y}_0$ in Figure 1, then the ex-ante stocking decision is x_E^*. Note that x_E^* is also the optimal ex-ante stocking decision in the absence of any constraint. The non-binding constraint implies that a pastoralist's animal stocking decision does not get restricted by requirement to meet the basic needs of consumption and/or loan repayments in bad states of nature. In other words, the pastoralists are well off enough to meet their basic needs in bad states of nature and they can freely decide about stocks to maximize their expected returns.

Figure 1



As depicted in Figure 1, the ex-ante stocking decision, x_E^*, leads to overstocking relative to the optimal stock in bad state, x_L^*, and understocking relative to the optimal stock in good state, x_H^*. Thus the ex-ante stock yields net revenues π_L^E & π_H^E, which are lower than the respective maxima, π_L^* & π_H^* that correspond to x_L^* & x_H^*. The stocking decision is homogenous for all the N pastoralists, which implies that the aggregate impact of on pasture will be determined by animal stock Nx_E^*. In case of bad state of nature the pasture will face degradation due to overstocking and in case of good state of nature the pasture will be underutilized. Note that even for a private property pasture the ex-ante stocking decision will be the similar to this case of common property resource with a fixed number of homogenous user however due to the common property regime a pastoralist does not completely internalize the damage inflicted on the pasture quality in bad state.

(ii) *Binding income constraint*. If the income constraint is binding, $\overline{Y}_0 < \overline{Y} \leq \overline{Y}_1$ in Figure1, then the stocking decision will be x^*_{EB}, where $x^*_L \leq x^*_{EB} < x^*_E$. Thus x^*_{EB} generates a return π^*_{EB} such that $\pi^*_L \leq \pi^*_{EB} < \pi^*_E$. The binding constraint implies that pastoralists are so poor that meeting their basic consumption and/or loan repayment need in bad states of nature drives their animal stocking decision, even at the expense of forgoing higher expected payoffs.

Due to the binding constraint, the ex-ante stock in this case is closer to the optimal stock in bad state, x^*_L, than in the case of non-binding constraint. It implies that the damage to the pasture quality due to overstocking in bad state in lower (or none if $\overline{Y} = \overline{Y}_1$) relative to the non-binding case. However, it also implies that the pasture use is much lower in good state of nature and therefore net revenues are much lower in good state of the nature relative to the non-binding case. Hence in case of pastoralists facing binding income constraints the reduced ex-ante animal stock implies less damage to the pasture in bad states but it also leads to lower average returns.

In sum, this case depicts a tradeoff between pastoralist welfare and the pasture quality. The binding requirement of meeting $\overline{Y}$ results in less damage to the pasture quality in bad state of nature due to lower stocks of animals, however it comes at the cost of reduced expected payoffs for the pastoralist.

(iii) *Unattainable income constraint*. For very high constraints, $\overline{Y} > \overline{Y}_1$ in Figure 1, there is no feasible solution as the minimum requirement is beyond the maximum feasible return in bad state. The inability to meet the minimum needs in the bad states of nature under this scenario can make a pastoralist quit pastoralism, which can have huge socio-economic implications.

In the next section, we introduce the index insurance to this model framework and assess its effect on stocking decision of pastoralists.

3 The Impact of Index Insurance

To assess the impact of index insurance, we compare the results of the baseline model presented in section 2 with the results from the following model with the insurance. We assume that the pastoralists are provided actuarially fair insurance, implying:

(2) $\gamma = \alpha \beta$

where,

β denotes the insurance payoff;

γ denotes the insurance premium;

$\alpha = p\ (R \leq R^*)$ is the probability of bad state;

R denotes actual rainfall and R^* denotes the level of rainfall that triggers the insurance payoff.

The pastoralists get the insurance payoff γ if rainfall is less than or equal to R^* and zero otherwise, which can be represented as:

(3) Insurance payoff $= \begin{cases} \beta & \text{if } R \leq R^* \\ 0 & \text{if } R > R^* \end{cases}$

Under this insurance structure, the premium and the payoff are independent of the stocking decision of the pastoralist. This type of insurance design can be used to provide uniform help to all the pastoralists covered by the insurance for meeting their basic sustenance requirements in bad states, as is the objective of many welfare programs especially those that are run by governments or development organizations. Under this structure of insurance, which is independent of the stocking decision, the optimization problem becomes:

(4) $$\underset{x_i}{Max}\,\pi_i = [\alpha . p_L . f(x_i, N, G_L) + \alpha\beta + (1-\alpha).p_H . f(x_i, N, G_H)] - p_0 . x_i - \gamma$$

s.t. $p_L . f(x_i, N, G_L) - p_0 . x_i + \beta - \gamma \geq \overline{Y}$

We also analyzed the model implications with an alternative insurance structure. In this case the insurance premium and payoffs are based on number of animal stock covered by the insurance. One needs to pay an insurance premium, γ, for each unit of animal stock insured and receives an insurance payoff β for each unit of animal stock covered by the insurance in bad state of nature. Thus the insurance payoff can be represented as:

(5) Insurance payoff $= \begin{cases} \beta x_i & \text{if } R \leq R^* \\ 0 & \text{if } R > R^* \end{cases}$

The insurance is assumed to be a fair insurance as before with $\gamma = \alpha\beta$, where $\alpha = p\ (R \leq R^*)$ is the probability of bad state. This type of structure can be more appealing for insurance companies as well as the pastoralists as the premiums and payoffs are per unit stock. In this case, user '*i*' makes the stocking decision x_i based on the following optimization problem:

(6) $$\underset{x_i}{Max}\, \pi_i = [\alpha.\{p_L.f(x_i, N, G_L) + \beta x_i\} + (1-\alpha)\{p_H.f(x_i, N, G_H)\}] - p_0.x_i - \gamma x_i$$

s.t. $p_L.f(x_i, N, G_L) + \beta x_i - p_0.x_i - \gamma x_i \geq \overline{Y}$

The optimization exercises for the two alternative structures of insurance are presented in the appendix. In both the cases the insurance affects the optimization exercise only through the income constraint and hence they have similar qualitative implications[5]. The implications of the results are as follows.

The introduction of insurance shifts the income constraint down due to the insurance payoff in bad state of nature. The vertical shift in the income constraint has the following effect on the stocking decision:

(i) *Non-binding constraint*. If the income constraint was non-binding in the absence of insurance ($\overline{Y} \leq \overline{Y}_0$ in Figure 1), it will be pushed further down by the insurance and hence it will remain non-binding in this scenario as well. As a result, the ex-ante stocking decision is x_E^*. Hence we can conclude that the stocking decision and therefore the pasture quality is not affected by the introduction of insurance.

(ii) *Binding income constraint*. In the case of an income constraint that was binding in the absence of insurance ($\overline{Y}_0 < \overline{Y} \leq \overline{Y}_1$ in Figure 1), the insurance would push the constraint downward. This downward shift of the constraint can potentially convert a binding constraint into non-binding one, depending on the magnitude of the insurance

[5]We also analyzed the potential impact of the two alternative insurance structures in a model without any constraint. The insurance has no impact on the stocking decisions in that model setup. Note that the neutral effect of insurance arises from the assumption of fair insurance. The optimization exercise for the unconstrained model is presented in the appendix.

payoff. Irrespective of the magnitude of the insurance payoff, the downward shift in the constraint reduces the minimum return requirement in bad state that leads to increase in the ex-ante stock relative to the scenario without insurance.

This result is attributed to the fact that the insurance payoff in a bad state helps a pastoralist to meet a portion of the minimum income requirement, $\overline{Y}$. It implies that in the bad state of nature the pastoralist now needs to ensure $\overline{Y} - \gamma$ or $\overline{Y} - \gamma x_i$, depending upon the insurance design. Since the binding constraint was making the pastoralist forgo higher expected payoffs in order to ensure $\overline{Y}$ in bad state by stocking at x^*_{EB}, where $x^*_L \leq x^*_{EB} < x^*_E$, relaxing the constraint by the insurance payoff amount, enables the pastoralist to move closer to x^*_E (or exactly to x^*_E if the insurance payoff $\geq \overline{Y}$) and generate higher expected returns. Thus the insurance facilitates higher ex-ante stocks and expected returns. It implies that there will be more animals on the pastures in low rainfall states because of the insurance. Thus the index insurance in this case would have a negative impact on the pasture in bad state of nature when the pasture is already under natural stress. Since the binding income constraint represents the case of extremely poor pastoralists, this undesired negative impact of index insurance on pasture in bad state raises a serious concern for long term sustainability of pastoralists who happen to fall under this case.

Note that in this case scenario, in good state of nature the insurance would result in better utilization of pasture and enhance the expected net revenue for the pastoralists. Thus the insurance can be beneficial for the pastoralists in terms of their short-term returns but it can potentially put the long-term pasture quality at stake.

(iii). *Unattainable income constraint*. An income constraint which was unattainable in the absence of insurance ($\overline{Y} > \overline{Y}_1$ in Figure 1), can become attainable as a binding or non-binding constraint in the presence of insurance and will provide a feasible solution if the magnitude of the insurance payoff is large enough. Hence the insurance has the potential of reducing the drop-out rates from pastoralism and may even bring ex-pastorals back to pastoralism. Thus it appears that in this constrained model set up, the index insurance may have substantial benefits. However, the insurance is most likely to push down the constraint from the non-feasible region to the binding constraint region, where it can have a negative impact on the pasture. If the insurance shifts the constraint from the unattainable region to the non-binding region then it is a win-win situation, but it is less likely to happen realistically as it would require huge insurance payoffs to make that transition in one step. Hence the transition from the non-feasible region to the binding constraint region is more plausible, which is the region associated with the negative impact insurance on pasture quality.

In sum, the results of our framework depict that the weather risk adversely affects pastoralists as they need to make ex-ante stocking decisions that not only generate suboptimal returns, but also puts strain on pasture quality in bad states of nature due to overstocking relative to the optimal. Although the insurance can help in reducing economic adversity for the pastoralists, it does not help in reducing the overstocking of animals relative to the optimal in bad state of nature. The most adverse scenario for pastoralists in which they barely manage to assure the minimum sustenance requirements in bad states of nature at the cost of foregoing higher expected profits, may be actually protecting the common property resource due to lower animal stocks that reduces the stress on pasture in bad states of nature. Under this scenario, by reducing or removing that minimum income generation constraint in bad states of nature, the insurance results in putting more stress on the common property pasture. Hence it is important for an implementation of the insurance to assess if that is the case, and if so, if there are complimentary policies that might need to be put in place to protect the vital resource, pasture.

Having diagnosed this potential undesired negative effect of index insurance on pasture quality, the next natural step is to look for plausible solutions for mitigating the problem so that the pastoralists can reap the benefits of the insurance without hampering the long-run sustainability of the pasture. We explore two such avenues in the next section.

4 Mitigating the Negative Impact of Insurance

We consider two sets of plausible interventions that can help in mitigating the potential negative impact of index insurance on pasture quality. One is a market based tool and another is a technological tool.

4.1 Market based intervention

In our model, the ex-ante stocking decision made in stage 1 determines the final pay-off for the pastoralists in stage 3. Since the net returns based on the ex-ante stocking are lower than the maximum feasible return in either states of natures, if a pastoralist could readjust the animal stock costlessly after the nature revealed itself in stage 2, he would reduce the stock to x_L^* and increase the stock to x_H^* in low and high rainfall states respectively to earn the optimal profits π_L^* & π_H^*. The restocking not only increases the returns of the pastoralists, it also reduces the pressure from the pasture in bad state, thereby has a positive impact on the pasture quality as well as pastoralists' income. However in the real world stock readjustment is not costless due to market imperfections like limited access to transportation and markets, markets that do not function all the year round, price volatility etc. (Barrett & Luseno, 2004). Hence if the stock readjustment is not costless and costs p_r per unit of stock readjustment, such that $0<p_r<\infty$, then the restocking decisions, x_L^R & x_H^R, in stage 2 of the decision making sequence can be derived from the following marginal conditions in the bad and good states respectively:

(7) $$p_L \frac{\partial f(x_i, N, G_L)}{\partial x_i} = p_r \text{ \& } p_H \frac{\partial f(x_i, N, G_H)}{\partial x_i} = p_r$$

In bad state the readjustment would involve reducing the stock till the marginal benefit from reducing a stock equals marginal readjustment cost and in good state it involves increasing the stock till the marginal benefit from increasing a stock equals marginal readjustment cost. Thus a positive readjustment cost would result in post-readjustment profits of π_L^R & π_H^R where $\pi_L^E < \pi_L^R < \pi_L^* \text{ \& } \pi_H^E < \pi_H^R < \pi_H^*$, which correspond to net stocks $(x_E^* - x_L^R) < x_L^* \text{ \& } (x_E^* + x_H^R) < x_H^*$ respectively. Our analysis in section 2 and 3 implicitly assumed prohibitively high readjustment cost, $p_r \to \infty$, which prevents any stock readjustment in stage 2. The readjustment cost in real world can be reduced by institutional interventions like improving transportation infrastructure, creating continuously functional markets, adopting price stabilization policies etc. Such market interventions can help in mitigating the negative impact of insurance on pasture quality as well as help in enhancing the returns for pastoralists.

4.2 Technological intervention – weather forecast

Provision of weather forecasts to pastoralists in the ex-ante decision making stage (stage 1) can help in reducing the uncertainty involved in the decision making. If the forecast is perfect i.e. predicts bad or good state with probability 1 in stage 1, then the optimization problem for a pastoralist becomes a problem without any uncertainty. The pastoralists would stock $x_L^* \;\&\; x_H^*$ animals in the bad and good forecast cases respectively. This would clearly solve the problem of overstocking and understocking in bad and good states of nature associated with ex-ante optimization with uncertainty. Thus introduction of a perfect forecast will *eliminate* the need for restocking in stage 2. This would generate optimal net revenue $\pi_L^* \;\&\; \pi_H^*$ in the bad and good states respectively which is equivalent to the case of zero readjustment cost in the absence of forecast. Thus from the policy perspective perfect forecasts can be used as an alternative tool that is equivalent to reducing stock readjustment cost to zero.

Note that a skilled forecast is consistent with the climatological pattern, which the pastoralists use to form their expectations in form of α, the probability of bad state and (1-α), the probability of good state. For example, if α is 0.2, then even a prefect forecast will predict a bad state with probability 1 in 2 out of every 10 forecasts and a good state with probability 1 in 8 out of every 10 forecasts. If we compare the long run net returns stream with perfect forecasts with the case of ex-ante decision making in the absence of forecast, it turns out that the perfect forecast increases the welfare of the pastoralists because we have:

(8) $$[\alpha\,\pi_L^* + (1-\alpha)\pi_H^*]\,withforecast > [\alpha\,\pi_L^u + (1-\alpha)\pi_H^u]\,withoutforecast$$

The impact of forecast on pasture quality depends on the relative magnitude of damage to the pasture in bad state due to overstocking and the benefit to the pasture in good state due to understocking in absence of forecast. If the damage in bad state outweighs the recovery in good state in the absence of forecast, then the forecast will benefit to the pasture quality as well.

However, we must recognize that perfect forecasts are not possible to generate. A more realistic scenario will be provision of forecast that has low margin of error. In case of an imperfect forecast, which cannot predict a bad or good state with probability 1, the lower the margin of forecast error, the lower would be the difference between the ex-ante stock and the optimal ex-post stock in each state. For example, if the forecast for bad state is closer to 0 (or 1) relative to the climatological α, which was the basis of ex-ante decision making for the pastoralists in the absence of forecast, and the nature reveals itself to be good (or bad), it would represent a low error forecast. If the pastoralists are provided such a low error forecast in stage 1, which predicts a bad state with probability close to 0, then they would stock closer to x_H^* and if the forecast predicts a bad state with probability close to 1, then they would stock closer to x_L^*. This would result in lowering the magnitude of overstocking and understocking in bad and good states respectively. Thus a low error forecast in stage 1 would *reduce* the need for restocking animals in stage 2 as the ex-ante stocking would be closer to the optimal state specific stocks, x_L^*or x_H^* compared to x_E^*. It also implies that even an imperfect forecast, with low margin of error will help in generating higher net returns relative to π_L^E & π_H^E. Hence weather forecasts with reasonably small margin of errors can enhance the welfare of the pastoralists as well as the pasture quality by reducing the need for ex-post stock readjustment. Hence an imperfect weather forecast can be essentially used as a potential substitute of reducing market imperfections for reducing stock readjustment cost. Hence it appears that technological (weather forecast) or institutional intervention (reducing market imperfections that are attribute to positive readjustment cost) or a combination of both can help in mitigating the potential negative effect of index insurance.

5 Summary and Conclusion

Index insurance is viewed as a powerful tool that can potentially help in weakening poverty traps for agriculturalists in developing countries. The strength of this insurance is that it does not suffer from the moral hazard problem associated with traditional yield based insurance. Thus the insurance is amore attractive to the insurance providers and may increase credit access for the agriculturalists while reducing their rainfall related risk. This paper investigates the potential impact of index insurance targeted for pastoralists on a vital rural natural resource, pasture. By comparing the animal stocking decision of pastoralists in the absence and presence of index insurance, our theoretical model shows that the introduction of index insurance can have an unintended negative impact on pasture quality under certain conditions. Our analysis focuses on common property pasture, a property right regime that is widely observed for pastures in many parts of the world and it can be efficiently managed or may suffer from the well-known 'tragedy of the commons'.

The model framework depicts that stocking decisions in the face of weather uncertainty not only has an adverse effect on the average returns for pastoralists, it also puts stress on the pasture in bad states of nature due to over stocking of animals relative to the optimal. We find that the index insurance has several benefits for pastoralists, which include its ability to enhance the average returns and restricting dropouts from pastoralism. However it fails to address the problem of overstocking and it can actually worsen the problem under certain conditions. Our model shows that the insurance has an unintended negative impact on pasture quality in case of pastoralists facing the most adverse scenario of restricting the animal stock in order to ensure a minimum return in bad states of nature so that they can meet their loan repayment and/or consumption needs at the cost of forgoing higher expected payoffs if the nature's outcome turned out to be good. This result arises due to the insurance payoff in bad states of nature that reduces or eliminates the need for assuring a minimum return in bad state of nature by restricting the animal stock at the cost of lower expected payoffs, a mechanism adopted in the absence of insurance which is costly for the pastolarist but beneficial for the pasture under distress in low rainfall states. This increased stress on pasture in bad states of nature can make recovery in good state more difficult or in the extreme case improbable, which has pronounced long term sustainability implications. If left unaddressed, the stress on pasture quality in bad states of nature might seriously undermine the benefits of the insurance in the long term. In implementing insurance for pastoralists, it would be worthwhile to understand if this is an important dynamic to address in the product design.

We explored some plausible avenues, technological and institutional interventions, which can mitigate the potential negative effect of the insurance on pasture quality. Technological intervention in the form of providing low error weather forecast at the ex-ante stocking stage can help in reducing the uncertainty in the decision making, thereby facilitating the pastoralists in moving towards the optimal stocks in the respective states of nature. It not only enhances the returns for the pastoralists, it also reduces the stress on pasture in bad states of nature. Institutional interventions like improving transportation networks, maintaining or creating regularly functioning markets, adopting price stabilization policies can reduce market imperfections, which can contribute towards reduction of the ex-post stock readjustment costs. These types of interventions can facilitate ex-post readjustment of stocks towards optimal in the respective states of nature and thereby enhance the revenue for the pastoralists as well as the pasture quality. Interestingly we find that low error weather forecasts can be used as a substitute of reducing stock readjustment cost. Thus the study highlights the need for the policy makers to carefully assess both the potential positive and negative impact of a new tool like the index insurance for pastoralists and adopt appropriate mechanisms to mitigate the potential negative effects which may otherwise hinder sustainable development.

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Appendix A: Constrained Optimization

The stocking decision in the absence of insurance

(A.1) $$\underset{x_i}{Max}\,\pi_i = [\alpha.p_L.f(x_i,N,G_L)+(1-\alpha).p_H.f(x_i,N,G_H)]-p_0.x_i$$

$$\text{s.t.}\quad p_L.f(x_i,N,G_L)-p_0.x_i \geq \overline{Y}$$

Lagrangean function:

(A.1.1) $$\begin{aligned} L &= [\alpha.p_L.f(x_i,N,G_L)+(1-\alpha).p_H.f(x_i,N,G_H)]-p_0.x_i \\ &+\lambda[p_L.f(x_i,N,G_L)-p_0.x_i-\overline{Y}] \end{aligned}$$

Let,

(A.1.2) $$A = [\alpha.p_L.f(x_i,N,G_L)+(1-\alpha).p_H.f(x_i,N,G_H)]-p_0.x_i$$

(A.1.3) $$B = p_L.f(x_i,N,G_L)-p_0.x_i$$

Note that *A* is the expected net revenue and *B* is the realized net revenue in bad state.

Then,

(A.1.4) $$\frac{\partial L}{\partial x_i}=\frac{\partial A}{\partial x_i}+\lambda\frac{\partial B}{\partial x_i} \qquad \& \qquad \frac{\partial L}{\partial \lambda}=B-\overline{Y}$$

The Kuhn Tucker conditions:

(A.1.5) $$\frac{\partial L}{\partial x_i}\leq 0,\ x_i\geq 0 \text{ and } x_i\frac{\partial L}{\partial x_i}=0;$$

(A.1.6) $$\frac{\partial L}{\partial \lambda}\geq 0,\ \lambda\geq 0 \text{ and } \lambda\frac{\partial L}{\partial \lambda}=0$$

yield the following four cases.

Case1: $$x_i>0,\lambda>0 \Rightarrow \frac{\partial L}{\partial x_i}=0 \text{ and } \frac{\partial L}{\partial \lambda}=0$$

(A.1.7) $\frac{\partial L}{\partial \lambda} = 0 \Rightarrow \overline{Y} = B$ => income constraint is binding.

(A.1.8) $\frac{\partial L}{\partial x_i} = 0 \Rightarrow \lambda = -\frac{\partial A}{\partial x_i} / \frac{\partial B}{\partial x_i} > 0$ => either $\frac{\partial A}{\partial x_i} < 0$ or $\frac{\partial B}{\partial x_i} < 0$

$\frac{\partial A}{\partial x_i} < 0$ => Marginal expected net revenue is negative => inefficient outcome.

Case 2: $x_i > 0, \lambda = 0 \Rightarrow \frac{\partial L}{\partial x_i} = 0$ and $\frac{\partial L}{\partial \lambda} > 0$

(A.1.9) $\lambda = 0$ and $\frac{\partial L}{\partial x_i} = 0 \Rightarrow \frac{\partial A}{\partial x_i} = 0$ => efficient outcome

(A.1.10) $x_i > 0$ and $\frac{\partial L}{\partial \lambda} > 0 \Rightarrow B > \overline{Y}$ => income constraint is not binding

Case 3: $x_i = 0, \lambda > 0 \Rightarrow \frac{\partial L}{\partial x_i} < 0$ and $\frac{\partial L}{\partial \lambda} = 0$

(A.1.11) $x_i = 0 \Rightarrow B = 0$ and $\frac{\partial L}{\partial \lambda} = 0 \Rightarrow \overline{Y} = 0$ =>contradiction

Case 4: $x_i = 0, \lambda = 0 \Rightarrow \frac{\partial L}{\partial x_i} < 0$ and $\frac{\partial L}{\partial \lambda} > 0$

(A.1.12) $x_i = 0 \Rightarrow B = 0$ and $\frac{\partial L}{\partial \lambda} > 0 \Rightarrow \overline{Y} < 0$ =>contradiction

Hence case 1 and case 2 are the two feasible cases, which correspond to the binding and the non-binding income constraint respectively. Case 3 and 4 are not feasible.

The stocking decision in the presence of insurance

If the insurance premium and payoff are independent of stocking decision, then user '*i*' makes the stocking decision x_i based on the following optimization problem:

(A.2)

$$\underset{x_i}{Max}\,\pi_i = [\alpha.\{p_L.f(x_i,N,G_L)+\beta\}+(1-\alpha)\{p_H.f(x_i,N,G_H)\}]-p_0.x_i-\gamma$$

$$\text{s.t.}\quad p_L.f(x_i,N,G_L)+\beta-p_0.x_i-\gamma \geq \overline{Y}$$

Lagrangean function:

(A.2.1) $$L=[\alpha.p_L.f(x_i,N,G_L)+(1-\alpha).p_H.f(x_i,N,G_H)]-p_0.x_i+\alpha\beta-\gamma+ \lambda[p_L.f(x_i,N,G_L)-p_0.x_i+\beta-\gamma-\overline{Y}]$$

Then,

(A.2.2) $\frac{\partial L}{\partial x_i}=\frac{\partial A}{\partial x_i}+\lambda\frac{\partial B}{\partial x_i}$ where A and B are specified as in (A.1.2) & (A.1.3)

Note that the insurance parameters drop out from the derivative as they are independent of the stocking decision.

(A.2.3) $\frac{\partial L}{\partial \lambda}=B+\beta-\gamma-\overline{Y}$. Note that the insurance affects the constraint.

The Kuhn Tucker conditions again yield four cases out of which two are feasible. We present the feasible cases below.

Case 1: $x_i>0,\lambda>0 \Rightarrow \frac{\partial L}{\partial x_i}=0$ and $\frac{\partial L}{\partial \lambda}=0$

(A.2.4) $\frac{\partial L}{\partial x_i}=0 \Rightarrow \lambda=-\frac{\partial A}{\partial x_i}/\frac{\partial B}{\partial x_i}>0$

(A.2.5) $\frac{\partial L}{\partial \lambda}=0 \Rightarrow \overline{Y}=B+\beta-\gamma$

Case 2: $x_i > 0, \lambda = 0 \Rightarrow \frac{\partial L}{\partial x_i} = 0$ and $\frac{\partial L}{\partial \lambda} > 0$

(A.2.6) $\lambda = 0$ and $\frac{\partial L}{\partial x_i} = 0 \Rightarrow \frac{\partial A}{\partial x_i} = 0$

(A.2.7) $x_i > 0$ and $\frac{\partial L}{\partial \lambda} > 0 \Rightarrow B + \beta - \gamma > \overline{Y}$

If the insurance premium and payoff are dependent on stocking decision, then user '*i*' makes the stocking decision x_i based on the following optimization problem:

(A.3) $\underset{x_i}{Max}\, \pi_i = [\alpha.\{p_L.f(x_i, N, G_L) + \beta x_i\} + (1-\alpha)\{p_H.f(x_i, N, G_H)\}] - p_0.x_i - \gamma x_i$

s.t. $p_L.f(x_i, N, G_L) + \beta x_i - p_0.x_i - \gamma x_i \geq \overline{Y}$

Lagrangean function:

(A.3.1)
$$L = [\alpha.p_L.f(x_i, N, G_L) + (1-\alpha).p_H.f(x_i, N, G_H)] - p_0.x_i + \alpha\beta x_i - \gamma x_i$$
$$+ \lambda[p_L.f(x_i, N, G_L) - p_0.x_i + \beta x_i - \gamma x_i - \overline{Y}]$$

Then,

(A.3.2) $\frac{\partial L}{\partial x_i} = \frac{\partial A}{\partial x_i} + \lambda \frac{\partial B}{\partial x_i} + \alpha\beta - \gamma = \frac{\partial A}{\partial x_i} + \lambda \frac{\partial B}{\partial x_i}$.

Note again that the insurance parameters drop out from the derivative because the insurance is a fair insurance i.e. $\alpha\beta=\gamma$.

(A.3.3) $\frac{\partial L}{\partial \lambda} = B + \beta x_i - \gamma x_i - \overline{Y}$. Note that the insurance affects the constraint.

The Kuhn Tucker conditions again yield four cases out of which two are feasible. We present the feasible cases below.

Case 1: $x_i > 0, \lambda > 0 \Rightarrow \frac{\partial L}{\partial x_i} = 0$ and $\frac{\partial L}{\partial \lambda} = 0$

(A.3.4) $$\frac{\partial L}{\partial x_i} = 0 \Rightarrow \lambda = -\frac{\partial A}{\partial x_i} / \frac{\partial B}{\partial x_i} > 0$$

(A.3.5) $$\frac{\partial L}{\partial \lambda} = 0 \Rightarrow \overline{Y} = B + \beta - \gamma$$

Case 2: $$x_i > 0, \lambda = 0 \Rightarrow \frac{\partial L}{\partial x_i} = 0 \text{ and } \frac{\partial L}{\partial \lambda} > 0$$

(A.3.6) $$\lambda = 0 \text{ and } \frac{\partial L}{\partial x_i} = 0 \Rightarrow \frac{\partial A}{\partial x_i} = 0$$

(A.3.7) $$x_i > 0 \text{ and } \frac{\partial L}{\partial \lambda} > 0 \Rightarrow B + \beta - \gamma > \overline{Y}$$

Appendix B. Unconstrained Optimization

Optimization without any insurance

In the absence of insurance, pastoralist '*i*' makes an ex-ante decision to stock x_{iE}^{*} animals based on the following optimization problem:

(B.1) $$\underset{x_i}{Max}\,\pi_i = [\alpha.p_L.f(x_i,N,G_L) + (1-\alpha).p_H.f(x_i,N,G_H)] - p_0.x_i$$

The x_{iE}^{*} is derived from the first order condition for optimization:

(B.1.1) $$\alpha.p_L.\frac{\partial f(x_i,N,G_L)}{\partial x_i} + (1-\alpha).p_H.\frac{\partial f(x_i,N,G_H)}{\partial x_i} = p_0$$

If the pastoralist knew about the state of the nature with certainty, in the bad state of nature, the optimal stocking decision would be x_L^{*} in the bad state, which is based on the following optimization:

(B.1.2) $$\underset{x_i}{Max}\,\pi_i = p_L.f(x_i,N,G_L) - p_0.x_i$$

with first order condition

(B.1.3) $$p_L.\frac{\partial f(x_i,N,G_L)}{\partial x_i} = p_0$$

And in the good state of nature the optimal stocking decision would be x_H^{*}, which is based on the following optimization:

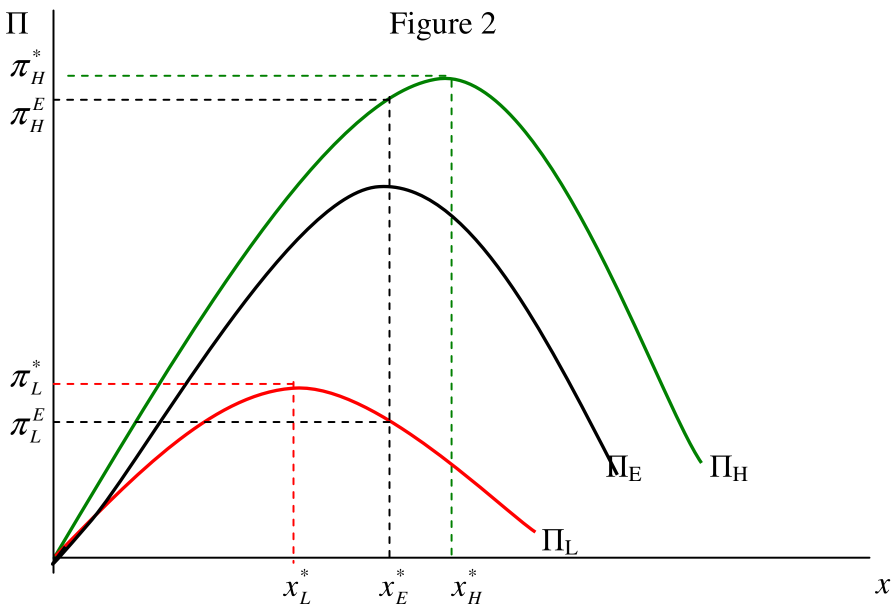
(B.1.4) $$\underset{x_i}{Max}\,\pi_i = p_H.f(x_i,N,G_H) - p_0.x_i$$

with first order condition

(B.1.5) $$p_H.\frac{\partial f(x_i,N,G_H)}{\partial x_i} = p_0$$

Based on the assumptions about the production function in good and bad states the stocking decisions and the corresponding net revenues can be presented graphically as follows:

Figure 2



Optimization in the presence of index insurance

Pastoralist '*i*' now faces the following optimization problem:

(B.2) $$\underset{x_i}{Max}\, \pi_i = [\alpha.p_L.f(x_i, N, G_L) + \alpha\beta + (1-\alpha).p_H.f(x_i, N, G_H)] - p_0.x_i - \gamma$$

Since the insurance enters as fixed cost and fixed benefit in the objective function, it does not have any affect the optimal stocking or restocking decision in this case as the first order condition is same as before:

(B.2.1) $$\alpha.p_L.\frac{\partial f(x_i, N, G_L)}{\partial x_i} + (1-\alpha).p_H.\frac{\partial f(x_i, N, G_H)}{\partial x_i} = p_0$$

Hence, we tested the model implications with an alternative insurance structure. In this case, the insurance premium, γ, and insurance payoff, β, are based on per unit stock, and the insurance is assumed to be a fair insurance as before i.e. $\gamma = \alpha\beta$. This type of structure can be more appealing for insurance companies as well as the pastoralists. The optimization problem under this set up will be as follows:

(B.3) $$\underset{x_i}{Max}\, \pi_i = [\alpha.p_L.f(x_i, N, G_L) + \alpha\beta x_i + (1-\alpha).p_H.f(x_i, N, G_H)] - p_0.x_i - \gamma x_i$$

The first order condition:

(B.3.1) $$\alpha.p_L.\frac{\partial f(x_i, N, G_L)}{\partial x_i} + (1-\alpha).p_H.\frac{\partial f(x_i, N, G_H)}{\partial x_i} = p_0 + \gamma - \alpha\beta$$

Note that first order conditions under both the insurance structures are identical due to the assumption of fair insurance, $\gamma = \alpha\beta$. Hence the change in the design of the instrument does not affect the marginal conditions, which implies that the ex-ante stocking decisions remains unaffected by the insurance. Thus the index insurance does not have any impact on the pasture quality. This unconstrained model is very unlikely to be observed in reality as pastoralists especially in arid and semi-arid regions who rely on common property pastures for their sustenance are constrained by several factors. Hence we focus on a model with a widely observed minimum income constraint.