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Production and insurance under regret aversion ☆

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ABSTRACT

This paper examines the behavior of a regret-averse producer facing revenue risk. To insure against the revenue risk, the producer can purchase a coinsurance contract with an endogenously chosen coinsurance rate. Regret-averse preferences are characterized by a utility function that includes disutility from having chosen ex-post suboptimal alternatives. We show that the regret-averse producer never fully insures against the revenue risk even though the coinsurance contract is actuarially fair. When the producer is sufficiently regret averse and the loss probability is high, we further show that the regret-averse producer chooses not to purchase the actuarially fair coinsurance contract. Even when purchasing the actuarially fair coinsurance contract is optimal, we derive sufficient conditions under which the regret-averse producer reduces the optimal output level as compared to that without the coinsurance contract. These results are distinct from those under pure risk aversion, thereby making the consideration of regret aversion crucial.

1. Introduction

Revenue insurance, such as multiple peril crop insurance (Mahul and Vermersch, 2000) and livestock revenue insurance (Hart et al., 2001), has been introduced for many agricultural products, which serves as a risk-sharing mechanism between farmers and insurers. The literature that examines the effect of revenue insurance on the behavior of a risk-averse producer is largely conducted within the von Neumann–Morgenstern expected utility context (see, e.g., Ford et al., 1996; Hau, 2006; Machnes, 1995; Machnes and Wong, 2003; Wong, 2000; to name just a few). Such an approach rules out the situation that the producer may have a desire to avoid consequences wherein the producer appears to have made ex-post suboptimal decisions, which are de facto optimal ex ante based on the information available at that time. To account for this consideration, Bell (1982, 1983) and Loomes and Sugden (1982) propose regret theory that defines regret as the disutility arising from not having chosen the ex-post optimal alternative, which is later axiomatized by Quiggin (1994) and Sugden (1993). Regret theory is supported by a large body of experimental literature that documents regret-averse preferences among individuals (see, e.g., Loomes, 1988; Loomes and Sugden, 1987; Loomes et al., 1992; Starmer and Sugden, 1993).

The purposes of this paper are to incorporate regret theory into the behavior of a producer under uncertainty in general, and examine how regret aversion affects the producer's production and insurance decisions in particular. We model uncertainty as a shock to the producer's revenue, which can be insured against by purchasing a coinsurance contract that the producer can choose a coinsurance rate. Following the seminal work of Braun and Muermann (2004) and Wong (2011), we characterize the producer's regret-averse preferences by a utility function that includes disutility from having chosen ex-post suboptimal alternatives. The extent of regret depends on the difference between the utility level of the actual profit and that of the maximum profit attained by making the optimal production and insurance decisions had the producer learned the true outcome of the revenue risk in advance.

In the absence of insurance against the revenue risk, we show that introducing regret aversion to the producer can induce the producer to produce more or less than the optimal output level that would have been chosen if the producer were purely risk averse. Since the regret-averse producer has to take into account the impact of regret, the optimal output level becomes less extreme as compared to that of the purely risk-averse producer. The global effect of regret aversion on the producer's production decision is therefore to reduce the sensitivity of the optimal output level to changes in the probability distribution of the revenue risk. We further show that the optimal output level is less sensitive to changes in the probability distribution of the revenue risk with an increase in the producer's degree of regret aversion, and becomes completely insensitive in the limiting case when the producer is infinitely regret averse.

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When the regret-averse producer can purchase the coinsurance contract that is actuarially fair, we show that full insurance against the revenue risk is never optimal because the producer would regret to a great extent when no loss actually occurs (see also Braun and Muermann (2004)). We further show two novel results. First, the regret-averse producer may not purchase the actuarially fair coinsurance contract. While risk aversion induces the producer to purchase insurance so as to reduce the variation of his/her profit, regret aversion gives rise to a countervailing incentive that induces the producer to purchase no insurance when the loss probability is high so as to minimize regret. We show that the incentive to opt for no insurance due to regret aversion dominates the incentive to opt for insurance due to risk aversion if the producer is sufficiently regret averse and the loss probability is high. Second, even when purchasing the actuarially fair coinsurance contract is optimal, the regret-averse producer does not necessarily produce more with than without the coinsurance contract. In the presence of insurance against the revenue risk, it is well-known from the literature that the risk-averse producer would like to produce more. Regret aversion, however, creates a countervailing incentive that induces the producer to produce less so as to minimize regret. When the producer is sufficiently regret averse and the loss probability is high, we show that the incentive to lower output due to regret aversion dominates the incentive to raise output due to risk aversion, thereby rendering the output-reducing effect of insurance that exists under regret aversion but not under risk aversion.

The rest of this paper is organized as follows. Section 2 delineates the model of a regret-averse producer facing revenue risk. Section 3 examines the global and marginal effects of regret aversion on the producer's production decision in the absence of insurance against the revenue risk. Section 4 characterizes the optimal production and insurance decisions of the regret-averse producer. The final section concludes.

2. The model

Consider a producer who produces a single commodity according to a deterministic cost function, $C(Q)$, where $Q\geq 0$ is the output level chosen, $C(0)=C'(0)=0$, and $C'(Q)>0$ and $C''(Q)>0$ for all $Q>0$. The output price is exogenously fixed at $P>0$ per unit. There is a shock such that a fraction, $\gamma\in(0,1]$, of the producer's revenue, PQ, is lost with probability $p\in(0,1)$. Given that a loss occurs, the producer's actual revenue is only $(1-\gamma)PQ$. To insure against such revenue risk, the producer can purchase a coinsurance contract with an endogenously chosen coinsurance rate, $\alpha\in[0,1]$.[1] Specifically, the producer pays an insurance premium, $(1+m)p\gamma\alpha PQ$, and receives an indemnity, $\gamma\alpha PQ$, in case of a loss, where $m\geq 0$ is the loading factor such that $(1+m)p<1$.[2] To focus on the pure effect of insurance on the behavior of the producer, we restrict our attention to the case that the coinsurance contract is actuarially fair, i.e., we set $m=0$.

For a given output level, Q, and a given coinsurance rate, α, the producer's profit, $\Pi_i(Q,\alpha)$, is given by

$$\Pi_i(Q,\alpha)=\begin{cases}(1-\gamma)PQ-C(Q)+(1-p)\gamma\alpha PQ & \text{if}\quad i=1,\\ PQ-C(Q)-p\gamma\alpha PQ & \text{if}\quad i=0,\end{cases}\tag{1}$$

where $i=1$ or 0, indicating whether a loss occurs or not, respectively. The producer purchases no insurance if $\alpha=0$, and opts for full insurance if $\alpha=1$. In the latter full-insurance case, the producer's profit becomes $\Pi_i(Q,1)=(1-p\gamma)PQ-C(Q)$, which is non-stochastic and thus is unaffected by the revenue risk.

Following Braun and Muermann (2004) and Wong (2011), we define the producer to be regret averse if his/her preferences are represented by the following "modified" utility function that includes some compensation for regret:

$$V(\Pi)=U(\Pi)-\beta G\left[U(\Pi^{max})-U(\Pi)\right],\tag{2}$$

where $U(\Pi)$ is a von Neumann–Morgenstern utility function with $U'(\Pi)>0$ and $U''(\Pi)<0$, $\beta\geq 0$ is a constant regret coefficient, and $G(\cdot)$ is a regret function with $G(0)=0$, $G'(\cdot)>0$, and $G''(\cdot)>0$. The regret function, $G(\cdot)$, depends on the difference between the utility levels of the actual profit, Π, and the maximum profit, Π^{max}, that the producer could have earned by making the optimal production and insurance decisions had the producer observed the realized value of the revenue shock. Since Π cannot exceed Π^{max}, the producer experiences disutility from forgoing the possibility of doing better due to the ignorance of the realized revenue shock. If $\beta=0$, the producer becomes a traditional risk-averse expected utility maximizer. It is evident from Eq. (2) that the producer is always risk averse and is also regret averse when $\beta>0$.

To characterize the regret-averse producer's optimal production and insurance decisions, we have to first derive the maximum profit, Π^{max}. Suppose that a loss occurs. Using Eq. (1) with $i=1$, we have

$$\Pi_1^{max}=\max_{Q\geq 0,\alpha\in[0,1]}(1-\gamma)PQ-C(Q)+(1-p)\gamma\alpha PQ = (1-p\gamma)PQ_1-C(Q_1),\tag{3}$$

where Q_1 solves $C'(Q_1)=(1-p\gamma)P$. On the other hand, if there is no loss, we use Eq. (1) with $i=0$ to derive

$$\Pi_0^{max}=\max_{Q\geq 0,\alpha\in[0,1]}PQ-C(Q)-p\gamma\alpha PQ = PQ_0-C(Q_0),\tag{4}$$

where Q_0 solves $C'(Q_0)=P$. It follows from $C''(Q)>0$ that $Q_1<Q_0$.

The ex-ante decision problem of the regret-averse producer is to choose an output level, Q, and a coinsurance rate, α, so as to maximize the expected value of his/her regret-theoretical utility function:

$$\max_{Q\geq 0,\alpha\in[0,1]} p\left\{U\left[\Pi_1(Q,\alpha)-\beta G\left\{U(\Pi_1^{max})-U\left[\Pi_1(Q,\alpha)\right]\right\}\right\}\right. \\ \left.+(1-p)\{U[\Pi_0(Q,\alpha)-\beta G\{U(\Pi_0^{max})-U[\Pi_0(Q,\alpha)]\}\}\right\},\tag{5}$$

where $\Pi_i(Q,\alpha)$ is given by Eq. (1) for $i=0$ and 1, and Π_1^{max} and Π_0^{max} are given by Eqs. (3) and (4), respectively. The first-order conditions for program (5) are given by

$$\begin{aligned}&p\left\{1+\beta G'\{U(\Pi_1^{max})-U[\Pi_1(Q^*,\alpha^*)]\}\right\}\\ &\quad\times U'[\Pi_1(Q^*,\alpha^*)]\left[(1-\gamma)P-C'(Q^*)+(1-p)\gamma\alpha^*P\right]\\ &\quad+(1-p)\left\{1+\beta G'\{U(\Pi_0^{max})-U[\Pi_0(Q^*,\alpha^*)]\}\right\}\\ &\quad\times U'[\Pi_0(Q^*,\alpha^*)]\left[P-C'(Q^*)-p\gamma\alpha^*P\right]=0,\end{aligned}\tag{6}$$

and

$$\begin{aligned}&p\left\{1+\beta G'\{U(\Pi_1^{max})-U[\Pi_1(Q^*,\alpha^*)]\}\right\}U'[\Pi_1(Q^*,\alpha^*)](1-p)\gamma PQ^*\\ &\quad-(1-p)\left\{1+\beta G'\{U(\Pi_0^{max})-U[\Pi_0(Q^*,\alpha^*)]\}\right\}U'[\Pi_0(Q^*,\alpha^*)]p\gamma PQ^*\leq 0,\end{aligned}\tag{7}$$

where an asterisk (*) indicates an optimal level, and condition (7) holds with equality if $\alpha^*>0$. The second-order conditions for program (5) are satisfied given the assumed properties of $U(\Pi)$, $C(Q)$, and $G(\cdot)$.

3. Optimal production decision in the absence of insurance

In this section, we consider the case that the producer is prohibited from insuring against the revenue risk, i.e., $\alpha\equiv 0$. To characterize the

[1] The qualitative results are unaffected if we replace the coinsurance contract by a deductible insurance contract.

[2] If $(1+m)p\geq 1$, the indemnity would not exceed the insurance premium when the loss occurs. In this case, the producer has no incentive to purchase any insurance.