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Production and hedging decisions under regret aversion☆

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ABSTRACT

In this paper, we investigate regret-averse firms' production and hedging behaviors. We first show that the separation theorem is still alive under regret aversion by proving that regret aversion is independent of the level of optimal production. On the other hand, we find that the full-hedging theorem does not always hold under regret aversion as the regret-averse firms take hedged positions different from those of risk-averse firms in some situations. With more regret aversion, regret-averse firms will hold smaller optimal hedging positions in an unbiased futures market. Furthermore, contrary to the conventional expectations, we show that banning firms from forward trading affects their production level in both directions.

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1. Introduction

Since the seminal work of Sandmo (1971), Holthausen (1979), Katz and Paroush (1979) and others, there has been much theoretical and empirical research on the economic behavior of the competitive firm under price risk. In classical economic theory under uncertainty, two main results are derived: the separation theorem and the full-hedging theorem. The separation theorem documents that for risk-averse firms, their risk attitude and the distribution of prices are independent of their optimal production decision. On the other hand, the full-hedging theorem tells us that if the futures price is unbiased, risk-averse firms take a fully hedged position to eliminate the risk of price uncertainty. For reference, see Broll and Zilcha (1992), Adam-Müller (1997), Broll and Eckwert (1998, 2000), and Lien (2000).

In this paper, we extend the theory by examining the production and hedging behavior of a competitive firm under the premise that the firm demonstrates both risk-averse behavior and regret-averse attitude. In recent years, there has been a growing literature on firm behavior that assumes not only risk aversion but also regret aversion. For example, if firms' prices turn out to be very high and sales turn out to be very good, firms might regret not producing more. Conversely, if prices turn out to be low and sales are poor, firms might regret over-producing. Savage (1951) is the first to propose that decision makers include regret in their decision-making processes. Bell (1982), Fishburn (1982), and Loomes and Sugden (1982, 1987) develop a formal analysis of regret theory, which is later extended by Sugden (1993) and Quiggin (1994). Following the pioneering work of Sandmo (1971) on the optimal output of a risk-averse firm under price uncertainty, Paroush and Venezia (1979) first assume that competitive firms have a regret-averse utility. Nonetheless, Braun and Muermann (2004) propose using a more specific regret-averse utility function that is easily managed. Egozcue and Wong (2012) and Wong (2014) are the first to study the behavior of a competitive firm when price is unknown with the regret-averse utility introduced by Braun and Muermann. Niu et al. (2014) further examine the production decision of a competitive firm with a regret-averse utility. Broll et al. (2015) study the behavior of a regret-averse firm when the exchange rate is uncertain. There are other applications of regret aversion, for example,

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the demand for insurance (Wong, 2012), portfolio investment (Barberis et al., 2006; Muermann et al., 2006), auctions (Engelbrecht-Wiggans and Katok, 2008; Feliz-Ozbay and Ozbay, 2007), newsvendor model (Perakis and Roels, 2008), and banking issues (Tsai, 2012). To apply the regret theory to finance, Wagner (2002) derives a Markowitz-type model of portfolio choice with variable regret aversion. Readers may refer to Bleichrodt and Wakker (2015) for a comprehensive review of the development of the regret theory.

As discussed above, some authors extend the production theory of the risk-averse firm to that of the regret-averse firm to investigate the optimal production decision without considering the presence of a futures market. On the other hand, some authors study the production and hedging behaviors of the risk-averse firm. In addition, Michenaud and Solnik (2008) apply regret theory to get solutions to optimal currency hedging choices. As far as we know, there is no previous work that studies the production and hedging behaviors of the regret-averse firm. Nonetheless, it is of great interest to study the effect of regret aversion on the optimal production and hedging decisions when a futures market exists. For example, it would be interesting to know whether the two notable results—the separation and full-hedging theorems—are still valid if firms are regret averse. Our paper provides a natural extension of Wong (2014) by adding the opportunity for regret-averse firms to trade in futures contracts. This is in the same spirit as Holthausen (1979), who adds this opportunity to Sandmo (1971) for risk-averse firms.

We first examine whether the separation theorem still holds for the regret-averse firm. It is well known (Niu, et al., 2014; Wong, 2014) that under certain sufficient conditions and without hedging, the optimal output level is smaller under uncertainty than under certainty. When a futures market exists, we find that regret aversion has no effect on the optimal production decision. To be precise, optimal output levels are the same for both risk-averse and regret-averse firms that will choose their optimal outputs when their marginal costs are equal to the futures price. These results imply that the separation theorem is still alive under regret aversion.

Thereafter, we examine the full-hedging theorem for the regret-averse firm. We find that sometimes both regret-averse and risk-averse competitive firms behave similarly, but, in other situations, they behave differently. For example, when the futures price is smaller than the expected price (contango market), both risk-averse and regret-averse firms will take under-hedged positions. When the expected price and the futures price are the same (unbiased futures market), the risk-averse competitive firm will take a fully hedged position, while the regret-averse competitive firm will still take an under-hedged position. Furthermore, when the futures price is slightly higher than the expected price (backwardation futures market), risk-averse firms will take an over-hedged position, but regret-averse firms could take an under-hedged, a fully hedged, or an over-hedged position, depending on the degree of regret aversion. These results imply that under regret aversion, the full-hedging theorem does not hold.

We conduct a comparative statics analysis and find that with more regret aversion, the optimal hedging position will become smaller in an unbiased futures market. Moreover, we find that the regret-averse firm optimally produces more or less in the absence than in the presence of a futures market. This result is different from the traditional wisdom that forward hedging always promotes production. The theory developed in our paper is not only useful for firms in managing their production levels and hedging positions, but it also aids firms' competitors, business partners, shareholders, and stock and bond investors in their investment decisions as well as assisting policy makers in their policy setting processes.

In Section 2, we state the assumptions and the model setup for a competitive firm that is not only risk averse but also regret averse. In Section 3, we derive the theory to describe the production and hedging behaviors for regret-averse competitive firms and compare the results with those for risk-averse competitive firms. The final section offers some discussions and conclusions.

2. Assumptions and the model setup

Suppose that a competitive firm produces Q units of a product at time 0 and will sell all units at time 1. We follow Broll et al. (2006) and others by assuming that the production cost, $C(Q)$, is strictly convex, such that $C(0) = C'(0) = 0$, $C'(\cdot) > 0$ and $C''(\cdot) > 0$, to reflect the firm's production technology to have decreasing returns to scale. The price, $\tilde{P}$, is random at time 1 with support on $[\underline{P}\overline{P}]$, such that $0 < \underline{P} < \overline{P} < \infty$. In addition, there is a corresponding futures contract that matures at time 1 with price P^f at time 0. We also assume that the producer wants to hedge against the risk that the price of his/her produced goods may drop so that he/she sells X[1] units of the product under the futures contract and he/she will deliver X units of the product against the futures contract at time 1. Letting π be the profit at time 1, we have

$$\tilde{\pi} = \tilde{P}(Q - X) + P^f X - C(Q) \,. \tag{2.1}$$

To address the notion of regret, we follow Braun and Muermann (2004) and others by employing the following bivariate (two-attribute) regret-averse utility function $\mathcal{V}$ to get the ex-post suboptimal decision:

$$\mathcal{V}(\pi, \pi^{max} - \pi) = \mathcal{U}(\pi) - \beta g(\pi^{max} - \pi), \tag{2.2}$$

in which the first term is the von Neumann–Morgenstern utility function $\mathcal{U}(\cdot)$ to reflect risk aversion satisfying $\mathcal{U}' > 0$ and $\mathcal{U}'' < 0$. The second term takes care of the firm's regret prospect. The regret function $g(\cdot)$ indicates the regret-averse attribute in which $g(0) = 0$, $g'(\cdot) > 0$, and $g''(\cdot) > 0$. The parameter $\beta \geq 0$ is the weight of the regret attribute or regret coefficient measuring the extent of regret aversion. π^{max} is the ex-post optimal profit that the firm could have earned if there were no price uncertainty.

In our framework, when the realized output price P is observed, X will be zero since there is no uncertainty. The optimal Q is calculated by maximizing the following function

$$\max_{Q \geq 0} \mathcal{U}(\pi) = \max_{Q \geq 0} \mathcal{U}\{PQ - C(Q)\}$$

and getting $C'(Q) = P$. When the value of P changes, the optimal Q changes accordingly. Thus, $\pi^{max}(P)$ appears in the form of $PQ(P) - C[Q(P)]$ with $C'[Q(P)] = P$. For example, if the value of the uncertain price $\tilde{P}$ is realized to be P_1, the manager will make production and hedging decisions based on P_1. In other words, the manager will make the optimal decision based on the realized product price. However, in practice the price is unknown and random. Thus, the π^{max} is also random and depends on every possible value of the price $\tilde{P}$.

In order to compare the difference between regret-averse and risk-averse firms, in this paper we also investigate production and hedging decisions when the competitive firm is risk averse. To get a risk-averse utility function, one could simply set $\beta = 0$ in (2.2).

3. The theory

We will use the term “proposition” to state new results obtained in this paper and “property” to state some well-known results or the inference drawn from the propositions obtained in this paper.

[1] We note that the hedging position X in our paper is different from the hedge ratio, which is set to be between 0 and 1, while X can be negative as well as greater than one. Readers may refer to Michenaud and Solnik (2008) for more discussion on the hedge ratio. We would like to show our appreciation to the anonymous reviewer who point out this problem.

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