Energy Economics 57 (2016) 59–65

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Hedging strategy for ethanol processing with copula distributions

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ARTICLE INFO

Article history:
Received 15 December 2014
Received in revised form 7 August 2015
Accepted 17 April 2016
Available online 2 May 2016

JEL classification:
D810
Q130
Q420

Keywords:
Ethanol
Hedging
Value at risk
Copula
Efficient frontier

ABSTRACT

It has become important for ethanol producers to hedge input and output price risks. The purpose of this paper is to analyze an ethanol-producing firm's strategy to reduce price risks for inputs and outputs. Corn is the primary input, and the outputs are ethanol, corn oil, distillers' dried grains (DDGs), and renewable identification numbers (RINs). A theoretical model is developed including margins and risk is measured using value at risk (VaR). An empirical model is developed and extended to VaR using copulas to analyze the marginal distribution and dependence structure for input and output prices on margins. Efficient frontier curves analyzing VaR with and without copula are discussed. The results compare varying risk-strategy measures for long corn, short corn, and combining short and long corn. Sensitivity analyses are conducted for functional changes in the margin as a result of ethanol price changes.

1. Introduction and background

There are extreme price risks in ethanol manufacturing from the purchase of feedstock to the sale of end-products. Indeed, there have been bankruptcies in this sector that are directly related to risk management (Wald, 2013). These risks are caused by a multitude of random variables that impact margins, including prices for corn, ethanol, distillers dried grains (DDGs), corn oil, and renewable energy identification numbers (RINs). Ethanol manufacturing involves purchases of raw input materials and sales of outputs. Only corn and ethanol are traded on commodity markets. Thus, the process of buying feedstock and selling finished products involves risk. Hedging can be used to mitigate flat-price risk, and forward contracts can be utilized to lock in deferred sale prices on inputs. Effective procurement and sales strategies can give ethanol producers a competitive advantage over rivals.

A major source of uncertainty is the price for output sales. Commodity processors use varying forms of forward contracts to lock in end-product prices. Without commitments from buyers for quantities or prices, processors are exposed to large price risks (Fu et al., 2010) and ethanol producers would incur losses if prices dropped dramatically. Hedging serves the purpose of providing a temporary substitute for anticipated transactions of the product (e.g., typically, referred to as 'anticipatory hedging'). Ultimately, futures and spot prices are correlated and, in the delivery process, converge to be equal (except for prescribed non-random differential) and it is this correlation that ties the spot market value to futures price. Even though processing firms produce one major refined output, several by-products are produced and sold. In some processing industries, futures or options contracts exist for outputs, allowing simultaneous hedging. In other industries, hedging decisions are complicated because futures or options do not exist for all end-products. Processors often hedge products with ingredient futures contracts while utilizing cross hedging to mitigate the price risk for other by-products.

The purpose of this paper is to analyze and determine optimal hedging strategies for an ethanol processor purchasing corn and selling ethanol, corn oil, DDGs, and RINs. The processor is assumed a blender of ethanol. Futures contracts are used as the hedging strategy to reduce the risk of procurement/sales in cash markets. The objective function determines the optimal hedge ratio given the mean and variability of returns and is simulated with and without copula dependence. Copulas provide more flexible dependence measures when dealing with asymmetric dependences because assumptions are not placed on the marginal distributions (Vose, 2008) and tail dependency can be incorporated. The mean-value at risk (MVaR) model with copula distributions was specified and used to determine the optimal hedging strategy, and the efficient frontier relationship between risk and return. This paper implements copula distributions on five random variables in the model, i.e. ethanol, corn (spot and futures prices), DDGS, and corn oil (cash prices). The most crucial variables, corn and ethanol prices, are hedged

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http://dx.doi.org/10.1016/j.eneco.2016.04.011

directly and others including corn oil and DDGS are cross hedged. The methodological motivation for this specification is to allow for a more flexible specification of interdependencies among related prices. Most previous studies on hedging use univariate distributions and interdependencies are captured using simple correlations or regressions which are limiting.

Section 2 summarizes recent literature. Section 3 introduces the theoretical model which is followed by Section 4 on copulas and the dependence structure. In Section 5, the empirical model is described. Section 6 summarizes the results, and Section 7 provides conclusions and implications. The paper extends and contributes to the literature in several dimensions. First is the derivation and comparison of different hedging strategies using a mean-VaR framework. Second, copula analyses for determining a marginal distribution relationship are used with interrelationships and joint distributions between input and output parameters. Finally, this paper extends the interpretation of the ethanol supply chain by integrating hedging and risk management concepts from the ethanol producer's perspective.

2. Related literature

Other studies have developed varying models to analyze risks in processing. Recent studies using traditional mean–variance analysis include the bakery industry (Wilson et al., 2006), soybean crushing industry (Dahlgran, 2005), canola and western barley industry (Mann, 2010), and cross-hedging DDGs (Brinker et al., 2007). Wagner (2001); Oberholtzer (2011) and recently Chen et al. (2015) focus on the flour industry. This paper focuses on an ethanol producer.

James (2008) provides a thorough review for energy trading. Studies about risk management for the ethanol industry are limited. Dahlgran (2009) analyzed direct hedging by ethanol producers. The results indicated the effectiveness of hedging ethanol inventories and corn crush. Risk management strategies include transactions designed to minimize exposure to business risks (Huchzermeier and Cohen, 1996). Quintino and David (2013) examined the proposed ethanol futures for the Brazilian markets to attract sufficient liquidity for market agents and analyzed different cross-hedging strategies in the ethanol supply chain for sugarcane. The results indicated viability for ethanol futures.

Chang et al. (2012) examined the long- and short-run asymmetric adjustments for spot and futures prices, namely corn, soybeans, sugar, and three cross pairs of spot price for each of the other agricultural products and an ethanol futures price. Results indicated that the spreads' asymmetric adjustments give narrowing futures consisting of Chicago spot, New York Harbor spot, and Western European (Rotterdam) spot. The results concluded that the spread adjustment with corn has the strongest long-run widening adjustment, and sugar showed the weakest narrowing adjustment. The empirical analysis indicated the importance of hedging spot prices for agricultural commodities with ethanol futures contracts.

Dal-Mas et al. (2011) analyzed the ethanol supply chain with multiple decision criteria and uncertain markets. A mixed integer programming framework was used to solve the resulting model. An Italian case study was used with the results showing that risk-mitigating preferences are essential for hedging and decision making within the ethanol supply chain when there are multiple feedstocks.

Langholtz et al. (2014) presented a risk-management framework to review climate-related hazards, exposure, and vulnerability for the bioenergy supply chain. The authors considered a risk-management strategy, projecting the future growth of bioenergy feedstocks in regions that were preferentially exposed to such hazards. The implications of climate change on the expansion of cellulosic feedstocks were discussed.

The approach in this study and the results differ from previous studies. Other studies use simpler specifications of the univariate and interdependent distributions. In addition, this study explores alternative hedging strategies and compares their results. Our approach differs in that it uses more flexible and encompassing distributions, and explores risk and returns of alternative hedging strategies. It also developed hedging strategies in the ethanol industry that integrates other end products such as corn oil, DDGS, and RINS (renewable identification number). More specifically, the paper, (1) developed a risk–return relationship incorporating copula to capture the dependency structure in ethanol futures and spot prices; (2) derived and compared different hedging strategies including short corn, long corn, and ethanol crushing; (3) determined optimal hedge ratios which were estimated for three alternative strategies including traditional hedge, linear dependence, and copula dependence; and (4) calculated utility, margins, risk, and hedge ratios varied by strategy and type of dependence.

3. Theoretical model

Assuming that cash and futures prices are correlated, processors should hold opposite positions in the futures to hedge raw-material purchases or end-product sales. Typically, fluctuations in the futures do not have perfect co-movement with the underlying asset. These deficiencies may result in less than optimal hedging and increases in risk. The expected return and risk functions for an ethanol processor are presented in this section.

3.1. Model specification

The timing of the hedging decisions, spot purchases, and product sales are illustrated in Fig. 1. Hedging of ingredients occurs m months ahead, when physical ingredients need to be acquired from the spot market at time t. Hedging of outputs occurs at time t while outputs are expected to be sold in the market at time $t + n$.

The duration of the hedging period m and n depends on processing firms' practices and operational decisions.

Expected returns for the ethanol producer are defined as follows:

$$E(\prod) = Q_{O,t+n}E\left(\dot{P}_{O,t+n}\right) - Q_{I,t}E\left(\dot{P}_{I,t}\right) + Q_{I,F,t-m}\left(E\left(\dot{P}_{I,F,t}\right) - \overline{P}_{I,F,t-m}\right) + Q_{O,F,t}\left(E\left(\dot{P}_{O,F,t+n}\right) - E\left(\dot{P}_{O,F,t}\right)\right) - C \quad (1)$$

where $E(\Pi)$ is the expected return of processing, $Q_{O,t+n}$ is the number of output units produced at time $t+n$, $Q_{I,t+n}$ is the quantity of inputs needed at period t, $Q_{I,F,t-m}$ is the quantity of futures hedged for inputs at time $t-m$, and $Q_{O,F,t}$ is the futures position hedged for outputs at time t. $\dot{P}_{O,t+n}$ is the price of processed products sold at time $t+n$; $\dot{P}_{I,t}$ is the price of inputs in the cash market at time t; $\dot{P}_{I,F,t}$ and $\overline{P}_{I,F,t-m}$ are the futures price hedged for inputs at time t and $t-m$, respectively; and $\dot{P}_{O,F,t+n}$ $\dot{P}_{O,F,t}$ are the futures price hedged for outputs at time $t+n$ and t, respectively.

C represents the non-ingredient cost of production, comprising operational and hedging transaction costs, and is assumed constant. Of course, the results would differ if these were not constant. Stochastic parameters are represented by the dot symbol above the variables.

The first term of Eq. (1) represents the revenue from selling products at$t+n$. The second term is the cost of ingredients at time t on the cash markets. The third and the fourth terms are payoffs from hedging; one for hedging input procurement costs, and the other for hedging output

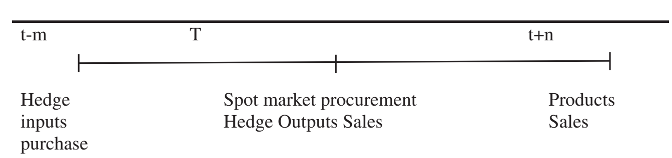

Fig. 1. Timeline for the hedging and procurement periods.