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Estimating the influence of U.S. ethanol policy on plant investment decisions: A real options analysis with two stochastic variables

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ABSTRACT

U.S. ethanol policies have contributed to changes in the levels and the volatilities of revenues and costs facing ethanol firms. The implications of these policies for optimal investment behavior are investigated through an extension of the real options framework that allows for the consideration of volatility in both revenue and cost components, as well as the correlation between them. The effects of policy affecting plant revenues dominate the effects of those policies affecting production costs. In the absence of these policies, much of the recent expansionary periods would have not existed and market conditions in the late-1990s would have led to some plant closures. We also show that, regardless of plant size, U.S. ethanol policy has narrowed the distance between the optimal entry and exit curves, implying a more narrow range of inactivity and indicative of a more volatile evolution for the industry than would have existed otherwise.

1. Introduction

Since 2005, the U.S. has witnessed a substantial increase in fuel ethanol production. This sizable growth has been due, at least in part, to the revision and/or creation of numerous federal, state, and local policies targeting both revenue enhancement and cost savings for ethanol producers. Over the same time period, these policies, coupled with other market effects have contributed to record-high and more volatile market prices for agricultural and energy commodities.

More recently, changes in market conditions have tempered the expansion of corn-ethanol production. Large increases in the price of corn, coupled with falling crude oil prices in 2008 and the more current economic downturn, have narrowed profit margins to corn-ethanol producers. In addition, the federal volumetric ethanol excise tax credit (VEETC) was reduced from 0.14 USD dm^{-3} to 0.12 USD dm^{-3} in the 2008 Farm Bill, and production and construction subsidies for corn-based ethanol facilities via the USDA Bioenergy Program have been reduced or eliminated.[1] These factors have led to a number of either temporary or permanent ethanol plant closures, stalled construction intentions, or plant sales at reduced valuations. For example, VeraSun Energy, the largest U.S. ethanol producer at the time, filed for bankruptcy in October 2008, halting construction plans on several sites and selling active plants to other ethanol producers or oil refiners (Energy Business Daily, 2009). Overall, the rate of expansion in ethanol production capacity averaged less than 1% (0.6%) per month in 2009, compared with 4.6% growth between 2005 and the end of 2008 (O'Brien and Woolverton, 2009).

Given the importance of U.S. biofuel production and the substantial risk on both the revenue and cost sides of ethanol production, the purpose of this article is to develop a better understanding of the effect of changing economic conditions and policy on investment decisions in ethanol production. Our approach centers on real options analysis (ROA) to better understand the investment behavior of ethanol firms and decisions of industry entry and exit. In addition to the now classic text by Dixit and Pindyck (1994), this paper rides on the shoulders of a large body of literature. These include Brennan and Schwartz (1985) who used ROA to evaluate natural resource investments and the ability to mothball and re-activate operations, and McDonald and Siegel (1986) who show that the option value of

Abbreviations: DDGS, distillers dried grains with soluble; VEETC, volumetric ethanol excise tax credit; ROA, real options analysis; GBM, geometric Brownian motion; ODE, ordinary differential equation; PDE, partial differential equation; FOB, free on board pricing; ADF, augmented Dickey–Fuller test.

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[1] The USDA Bioenergy Program was terminated in 2006 and replaced with a new Bioenergy Program for Advanced Biofuels where firms who produce biofuels from corn kernel starch are not eligible for funding (USDA, 2010a).

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risky investments may greatly increase benefit–cost ratios above one before the investment is undertaken. Kulatilaka (1986) and Trigeorgis (1996) examine the value of flexibility in alternative investment decisions, multi-stage projects, and switching conditions in a real options framework. Similarly, Majd and Pindyck (1987) examined the value of options afforded by flexibility when information arrives at different times during a sequence of investments, in particular showing that basing decisions on standard net present value calculations can result in significant opportunity losses.

Further ROA applications to natural resource investments were developed by Paddock et al. (1988) to value offshore petroleum leases, and by Clarke and Reed (1989), Insley (2002) and Reed and Clarke (1990) to determine when to optimally cut a stand of trees when price and/or growth in timber volume are stochastic. In environmental economics, Conrad (1997) used ROA to determine a damage threshold that would trigger an investment to slow global warming, while Pindyck (2007) discusses opposing uncertainties that arise when considering costly irreversible investments to slow global warming. Notable reviews of real options and investment under uncertainty literature are provided by Carruth et al. (2000), Pindyck (1991), and Schwartz and Trigeorgis (2001).

Our ROA approach and ethanol policy application make several important contributions to the literature. To begin, we extend the real options framework by incorporating multiple sources of stochastic behavior to better understand the investment behavior of firms. To date, agriculturally-based applications of ROA have been generally limited to models with a single random component, most often some measure of net return or profitability.[2] However, most of these models ignore the stochastic details of the individual components that are particularly important for policy analysis.

Our approach addresses this limitation directly. In particular, we extend the traditional one-variable ROA approach to accommodate two stochastic variables (namely unit revenues and costs), derive closed-form analytical solutions to the value functions, and then solve for the optimal entry and exit triggers. While the framework increases the computational burden relative to the traditional approach, we are now able to model revenue and cost separately (as well as the relationship between them) and investigate the influence of individual variance and covariance effects on optimal switching conditions.

Functional approximation procedures are necessary to solve optimal switching problems when analytical solutions cannot be determined (e.g., Fackler, 2004; Miranda and Fackler, 2002). By taking advantage of homogeneity in the value functions, our model formulation is simplified allowing for the existence of analytical solutions, and where optimal entry and exit trigger conditions can be solved for in a manner similar to a (reduced form) one-variable approach. The derivation of closed-form solutions to the value functions reduces the overall reliance on numerical approximation that should also contribute to their empirical precision (Dixit and Pindyck, 1994, p. 209). To investigate the significance of our extensions, we compare the new results to those from a traditional single-variable net return model specification.

Further, to facilitate policy analysis, we explicitly separate the effects of those financial incentives that affect revenue from those that affect cost. While considerable recent literature has evaluated more aggregate market or industry effects of ethanol policy, along with consequences for social welfare (see de Gorter and Just, 2010, for a useful summary), less attention has been focused on the influence of policies on firm-level investment decisions. To conduct the policy analysis, we utilize procedures from existing literature to estimate historical prices for ethanol, corn, and distillers dried grains with solubles (DDGS) that would have existed in the absence of ethanol policy. These alternative price series are then utilized within the model framework and the solutions are compared with those based on actual prices. While our present empirical application focuses on ethanol production from corn, such a framework may well facilitate a similar understanding of the factors that will influence investments in cellulosic ethanol, once that technology is proven.

We begin the remainder of the article by developing the conceptual model of optimal entry and exit for the case of two stochastic, potentially correlated, variables. This is followed by a discussion of the historical price series developed under alternative policy scenarios, and the estimation of stochastic-process parameters. The empirical results follow, comparing optimal entry–exit curves under alternative RO models (i.e., one- and two-variable cases) and policy scenarios (i.e., with and without policy). We close with conclusions, considerations for policy development, and directions for future research.

2. Conceptual framework

The main construct behind ROA is to assess the combined effect of both flexibility and irreversibility on the decision to invest and providing gains over conventional net present value (NPV) approaches. Increasing uncertainty raises the option value of waiting to invest. While a firm waits to invest, it gives up any returns from making the investment sooner, but by waiting for more information, improves the chances of making the correct investment decision later. Flexibility involves valuing the option value of waiting to invest (disinvest) against the incentive to invest (exit).

As shown by Dixit (1989), strict irreversibility is not required in ROA, rather the initial cost of the investment need only be partially sunk. Industry-specific (e.g., ethanol) investment expenditures (i.e., positive costs of entry or exit), provide support to the notion of sunk costs and at least partial irreversibility. Thus, specialized investments in a plant to produce ethanol, even if that plant could be retrofitted for another production process, results in option values.

In a competitive market, when a firm observes prices and responds, it is expected that other profit-maximizing firms will do the same, thus affecting market prices and investment decisions. However, Dixit and Pindyck (1994, pp. 288–292) show that a competitive firm can make the correct investment decision by acting myopically in the matter of future competitive entry, and acting as it were the last firm to enter the industry.

2.1. Stochastic processes

Following Dixit (1989), consider a fixed, linear, production technology transforming corn grain into ethanol and byproducts, and a discount rate of $\delta>0$. An idle project can be activated with an initial sunk investment cost k, expressed in USD dm^{-3} of plant production capacity. For operating plants, there is an exit (or shut-down) cost per unit of output, l, to close it. While in operation, the plant produces a fixed outflow of product each year and, for ease of exposition, it is normalized to unity. The operating plant receives unit revenues of y and incurs unit operating costs of x per dm^3 of ethanol produced. In this application, y consists of sales of ethanol (y_e) and byproducts (y_{bp}), such that $y=y_e+y_{bp}$. Operating costs include corn feedstock costs (x_c) and other operating costs (x_{oc}), such that $x=x_c+x_{oc}$. Finally, define the firm's net returns as $p=y-x$.

The stochastic variables are assumed to evolve according to Geometric Brownian motion (GBM). Accordingly, the cost and revenue components are modeled as individual, potentially correlated, GBMs, or:

$$dx = \mu_x x dt + \sigma_x x dz_x \tag{1}$$

[2] A useful summary of RO applications of investments in agriculture is found in Luo (2009). In particular to ethanol investment applications, Pederson and Zou (2008) use a net cash flow measure when considering plant expansion, Schmit et al. (2009) use an ethanol gross margin in identifying triggers for entry and exit, and Kirby and Davison (2010) present a RO-like valuation of an ethanol plant as a spark spread between corn and gasoline prices.