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Market Analysis of Ethanol Capacity

Xiaowei Cai[ⓘa] and Kyle W. Stiegert[b]

[a] *Assistant Professor, Department of Agribusiness, 1 Grand Ave., California Polytechnic State University, San Luis Obispo, California, 93407, USA*

[b] *Professor, Department of Agricultural and Applied Economics 427 Lorch Street, University of Wisconsin, Madison, Wisconsin, 53706, USA*

Abstract

The ethanol industry experienced rapid growth and capacity expansion during the mid-2000s. The fast expansion could result from the high industry profitability in 2005 and 2006. The present study applies the real options approach to analyze the U.S. corn ethanol industry and derive the optimal industry manufacturing capacities during 1999 and 2010. The optimal capacity is dependent on various parameters such as market uncertainty, processing margin, marginal variable cost, and incremental investment cost. The major finding is that the industry-wide capacity expansions occurred in 2007 and 2008 might not have been recommended by the real options model. Driven by the potential high market profitability, the industry might have been expanded to a level higher than optimal.

Keywords: ethanol, optimal capacity, real options, processing margin

ⓘCorresponding author: Tel: + 1 805.756.5011
Email: X. Cai: cai@calpoly.edu
K. W. Stiegert: kwstiegert@wisc.edu

Introduction

Because the production capacity decisions in capital-intensive industries are usually irreversible, selecting the appropriate level of investment could be truly important as well as risky. Specifically, if the firm misses the best timing to expand capacity, its short-run profitability is affected and it might lose the market share. In addition, its competitive position in the industry in the long term might as well be affected. However, if the firm over-expands its capacity, the fixed cost of managing the excess supply and the opportunity cost of holding the excess supply could be enormous. The appropriate capacity decision is especially critical in those industries that produce homogeneous output, such as the ethanol industry. The firms in this industry are not differentiated by product. Therefore, their production and profitability could be affected by the others' mistaken capacity decisions (Stiegert and Hertel 1997).

The structure of the U.S. corn ethanol industry has changed dramatically over the past 15 years. Specifically, the number of firms has increased by more than three times from 50 in 1999 to 189 in 2010 (Figure 1). As of January 2010, the vast majority of the firms are in the Midwest where corns are massively produced (Figure 2).

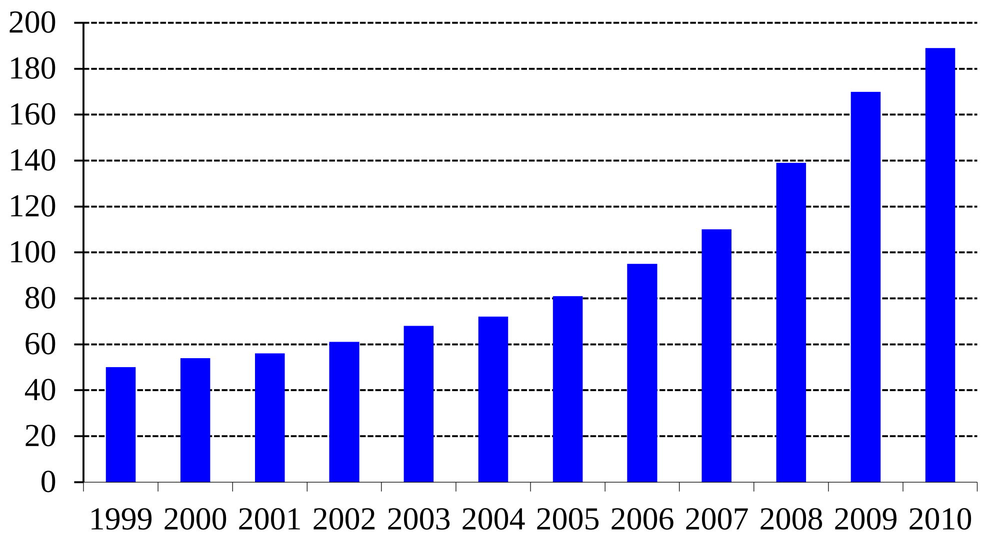

Figure 1. Number of Ethanol Plants, 1999-2010
Source. RFA 2011.

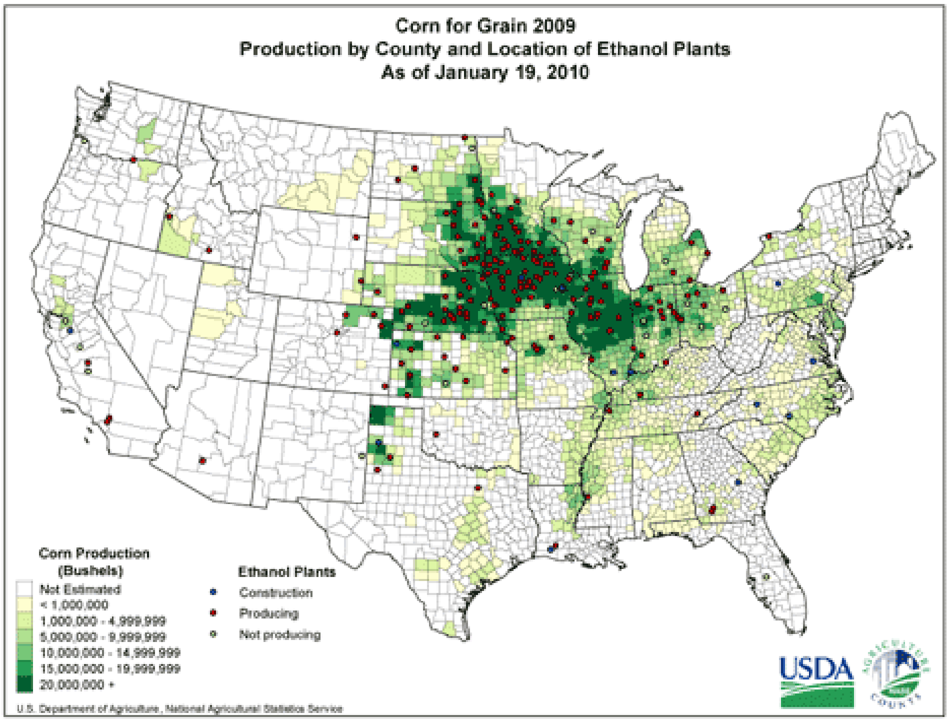

Figure 2. Location of U.S. Ethanol Plants, January 2010
Source. USDA

As the number of ethanol plants rises, the ethanol production and capacity both have increased by over 10 times since 1999 (Figure 3). Currently, the ethanol industry is comprised of nearly 200 plants with an annual capacity of 13.5 billion gallons. Dry mill plants account for more than 70 percent of capacity and virtually all new ethanol plants under construction are dry mills (U.S. Department of Energy 2010). The dramatic increase in production and capacity during the mid-2000s could be attributed to reduced grain prices, increased oil prices, the elimination of MTBE use in several States (Eidman 2007), and the federal incentives for ethanol. There are numerous federal and state policies that support the corn ethanol industry. For examples, Renewable Fuel Standard (RFS) 2005 required that 7.5 billion gallons of renewable fuels be blended with gasoline by 2012. The subsequent RFS 2007 required that 36 billion gallons of renewable fuels be used in the nation's motor fuel supply by 2022 (U.S. Department of Energy 2010). In addition, Cox and Hug (2010) estimated that the U.S. government has provided $17 billion of ethanol subsidies between 2005 and 2009. Meanwhile, the domestic ethanol producers were protected by a $0.54/gallon import tariff from foreign competitors, mainly from Brazilian ethanol producers.

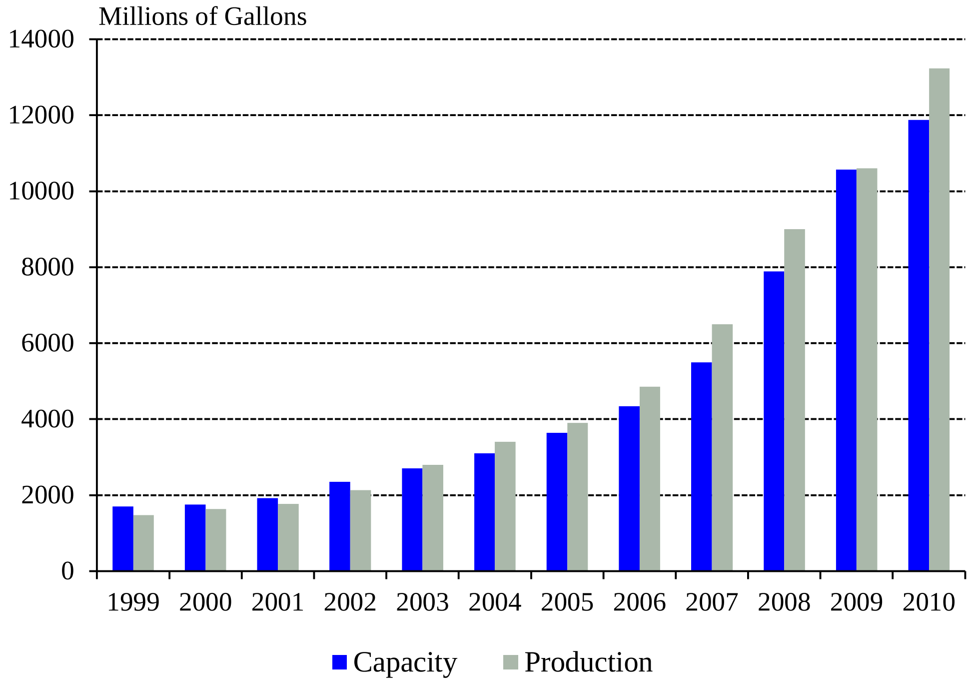

Figure 3. U.S. Ethanol Capacity and Production, 1999-2010
Source. RFA 2011

As shown in Figure 4, during the first couple of years in the 2000s, there was little capacity expansion in the ethanol industry. Since 2002, this industry has seen an increasing expansion until 2008. The capacity expansion numbers really stood out in 2007 and 2008. This is mainly because the ethanol industry experienced significant profitability in the two years earlier (Caphart 2009). From 2008 to early 2009, the ethanol prices kept increasing while demand for ethanol dropped (Caphart 2009). As a result, the capacity expansion continued but at a much slower rate. With the economic recession, demand for alternative energy including ethanol continued to decrease and banks became more cautious about risk and lending, the ethanol production reduced further. In 2011, the capacity expansion declined significantly to the 2003 level.

In practice, most corporate investment decisions are based on the traditional discounted cash flow methods (DCF), such as the standard net present value approach (NPV) or internal rate of return (IRR). However, in the presence of uncertainty about future margin and irreversible investment, the application of DCF methods could be problematic. The DCF methods do not consider firms' call options on future investment and hence might miss important dimensions that shape the investment decision (Stiegert and Hertel 1997).

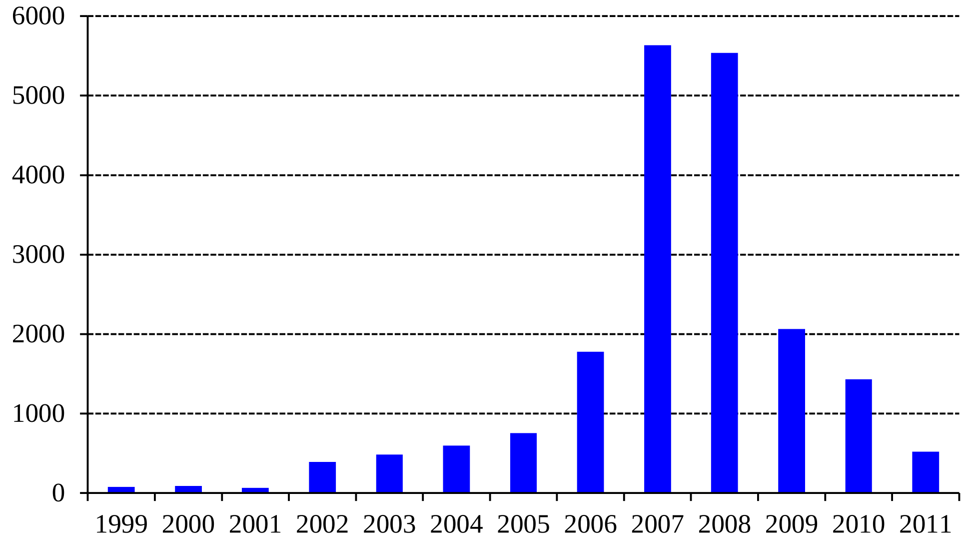

Figure 4. Ethanol Capacity Expansion, 1999-2011
Source. RFA 2011

In the literature, the NPV and IRR approaches have been widely used for evaluating ethanol investments such as Whims (2002), Gallagher et al. (2007), and Ellinger (2007). With the real options approaches developed by financial economists (such as Bowban et al. 2001; Aguerrevere 2003; Dangl 1999; Dixit and Pindyck 1994), the applied real options approach has been adopted to examine various agricultural investments, such as the ammonia industry, dairy farming, forestry, irrigation system and etc. (Stiegert and Hertel 1997; Duku-Kaakyire and Nanang 2002; Carey and Zilberman 2002; Tauer 2006; Bockman 2006; Ghoddusi 2009). In recent years, applied economists began to use applied real options approach to evaluate firms' investment in the ethanol industry (e.g., Pederson and Zou 2009; Schmit et al. 2008, 2009a, 2009b).

However, no prior research has been conducted to evaluate the ethanol industry's historical optimal capacity levels using real options approach. In the present study, there are three specific objectives. First, we develop a real options model to examine the bases for the firms' decision with regard to capacity expansion. Firms in the ethanol industry face market uncertainty related to input supplies, input and output prices, competition from overseas, and irreversibility feature of their capital investments. Given the production knowledge, the management skills and the patents, firms have the options to wait (i.e., growth option) before making the irreversible large investments to expand capacity. The growth option makes future investment opportunities attempting because better decisions can be made given the additional market information. Therefore, investing today is riskier and might require more returns than what the traditional DCF methods would suggest.

We first estimate the values of the growth option based on various parameters from 1999 to 2010. And we analyze how these parameters influence the evolution of the U.S. corn ethanol industry. Moreover, we derive the optimal levels of capacity in this industry based on the trade-off between the growth option values and the expected benefit of investment. Finally, we make a comparison between the observed industry capacities and derived optimal capacities to determine whether the industry experienced overcapacity or under-capacity during the study years.

Our estimation results show that there is a discrepancy between the optimal capacity and the real capacity in 2007 and 2008. The ethanol capacity expansions in these two years could be related to the industry-wide high margins and profitability during 2005 and 2006. However, the ethanol industry experienced more capacity expansion than the optimal expansion levels suggested by the real options model.

The remainder of the paper is organized as follows. The conceptual model and the foundations of the real options modeling are presented in Section 2. Section 3 presents the parameter estimation procedure, the model estimation results and the sensitivity analyses. The last section concludes.

Conceptual Model

Corn-ethanol plants produce ethanol from corn and natural gas with the by-product DDGs. Returns to the corn ethanol investments are tied closely to the firm's gross processing margin given by the following equation:

$$(1)\ M = p_e - \theta_1 p_c - \theta_2 p_g$$

where θ_1 and θ_2 are conversion ratios for corn-ethanol and for natural gas-ethanol respectively[1]. p_c is the net price of corn in $/bushel, and p_g is the natural gas price in $/MMBtu. The net price of corn is obtained by deducting the price of DDGs from the price of corn. In reality, there are various sources of uncertainties for the ethanol plants, such as the fluctuating input (i.e., corn and natural gas) prices, gasoline prices, outdated technology, closing facilities and consolidations, short corn supplies in certain years due to the weather problems, government subsidy changes, and global competitions. These uncertainties all affect blenders' gross processing margin.

The ethanol industry has been receiving the federal tax incentive since 1984. So tax credit needs to be added to the processing margin equation. The tax credit was $0.54/gallon between 1990 and 1999. The 1998 Transportation Equity Act reduced the credit to $0.53/gallon for 2001 and 2002, $0.52/gallon for 2003 and 2004, and $0.51/gallon through September 2007. The 2008 Farm Bill reduced the Volumetric Ethanol Excise Tax Credit to $0.45/gallon. It was determined in the American Jobs Creation Act of 2004 that the federal tax incentive would be extended through December 31, 2010 (US Department of Energy 2010).

Table 1 contains the corn prices, the ethanol prices, tax credit and the gross processing margins for ethanol blenders. The processing margin is the price of ethanol subtracted by the net corn price and the natural gas price. Comparing with 2001, processing margins in 2002 and 2003

[1] Based on EPA (2009), $\theta_1 = 0.36$ and $\theta_1 = 0.035$. This means that 1 bushel of corn can produce 0.36 gallons of ethanol and 1 MMBtu of natural gas can produce 0.035 gallons of ethanol.

dropped from \$1.41/gallon to \$0.97/gallon and \$1.18/gallon respectively because the ethanol prices reduced while the corn prices increased in those two years. Between 2003 and 2006, processing margins increased fast from less than \$1.20/gallon to almost \$2.00/gallon mainly due to the ethanol price increases. In 2006, the processing margin hit a record high in the first decade of the 21st century. However, the processing margin began to drop again in 2007 and the decreasing trend continued after 2008. From 2009 to 2010, the ethanol industry experienced low margins due to the effects of the economic and financial crisis, lower gasoline prices, and reduced government tax credit.

Table 1. Annual Capacity and Costs for the Ethanol Industry, 1999-2010

Year	Annual Capacity (millions of gallons)	Ethanol (\$/gallon)	Corn (\$/bushel)	DDGs (\$/bushel)	Natural Gas (\$/MMBtu)	Tax Credit (\$/gallon)	Margin (\$/gallon)
1999	1701.7	0.98	1.82	0.68	5.06	0.54	1.13
2000	1748.7	1.35	1.85	0.69	6.43	0.54	1.46
2001	1921.9	1.48	1.97	0.68	8.71	0.53	1.41
2002	2347.3	1.12	2.32	0.75	6.18	0.53	0.97
2003	2706.8	1.35	2.42	0.98	7.83	0.52	1.18
2004	3100.8	1.69	2.06	0.65	9.06	0.52	1.48
2005	3643.7	1.80	2	0.73	10.68	0.51	1.53
2006	4336.4	2.58	3.04	0.93	11.3	0.51	1.93
2007	5493.4	2.24	4.2	1.33	11.15	0.51	1.29
2008	7888.4	2.47	4.06	0.99	11.11	0.45	1.34
2009	10569.4	1.79	3.55	0.98	9.34	0.45	0.93
2010	11877.4	1.93	3.98	1.08	8.96	0.45	0.95

Note. The margin numbers are in 2006 dollars.

The market uncertainty not only affects the ethanol market, but the corn and natural gas markets as well. In addition, the ethanol market is influenced by the gasoline market, such as the fluctuating oil prices. Considering the multiple uncertain factors and the pattern of the historical margin movement, we follow Guthrie (2009) and assume that the gross processing margin in the ethanol industry evolves as a mean-reverting geometric Brownian motion:

$$(2)\quad M_{t+1} - M_t = \alpha(M^e - M_t)\Delta t + \sigma\, dW_t$$

where α is mean reversion rate which is the speed at which the processing margins revert, M^e is the long-run margin equilibrium level, σ is the instantaneous standard deviation per unit time and it is a measure of the process volatility, and W_t is a Brownian motion and dW_t is normally distributed as $N(0, \phi^2)$.

We assume the net variable costs are a non-stochastic linear function of output which implies a flat net marginal cost: $C(Q) = cQ,$ where c is the marginal cost for the net variable inputs and Q is the production quantity. The variable costs include enzymes, yeasts, other processing chemicals and antibiotics, electricity, water, repairs and maintenance, transportation, labor, management and quality control, real estate taxes, licenses and insurance. Therefore, the firm's instantaneous profit at time *t* is determined by the production, the gross processing margin and variable costs at *t*:

$$(3)\quad \pi(M_t, Q, c) = Max(M_t Q - cQ)$$

However, there is a time lag between construction and completion, and it is denoted by *h*. For example, if *h* = 3, it takes three years for the ethanol plant to complete the construction and the units under construction now will be available for use in three years. Therefore, the firm's decision with regard to marginal capacity expansion at time *t* is not dependent on the profit at time *t*, but rather the profit flow during [*t*-*h*, *t*].

The value of the marginal unit of capacity is a function of the investment cost for each unit of capacity construction/expansion *k* and the stochastic shock to the processing margin. Let ΔF(*K*, M) be the value of investment option when the intended marginal capacity is *K* and the current processing margin is M. So the exercise price of the call option is the cost of construction. The value of incremental unit of capacity is denoted by ΔV(K, M), which is the sum of discounted cash flow. The optimal capacity solution is subject to the following conditions:

$$\begin{matrix} 4(a) \\ 4(b) \\ 4(c) \end{matrix} \begin{cases} \Delta \mathrm{F}(\mathrm{K}; 0) = 0 \\ \Delta \mathrm{F}(\mathrm{K}; \mathrm{M}^*) = \Delta \mathrm{V}(\mathrm{K}; \mathrm{M}^*) - \mathrm{k} \\ \Delta \mathrm{F_M}(\mathrm{K}; \mathrm{M}^*) = \Delta \mathrm{V_M}(\mathrm{K}; \mathrm{M}^*) \end{cases}$$

Equation (4a) specifies that the stochastic process would end if *M* goes to 0. It is the lower absorbing barrier of the stochastic process. Equation (4b) is the value-matching optimality condition. M^* is the strike value for exercising the option to invest. At the optimal capacity level, the incremental value of installed capacity will equal the incremental costs. Condition (4c) is the smooth pasting condition. At the optimal solution, the derivatives of the two functions should equal.

Parameter Estimation Procedure and Estimation Results

In order to estimate the parameters in equation (2), we start estimating the AR(1) model for the gross processing margin using the annual data from 1990 to 2010:

$$(5)\ M_{t+1} - M_t = \alpha_0 + \alpha_1 M_t + \mu_{t+1} = 0.773 - 0.587\, M_t + \mu_{t+1}$$

where the variance of μ_{t+1}, φ^2, is 0.071. We then derive the values of the parameters in equation (2) based on the equations below:

$$(6)\quad \alpha = \frac{-\log(1+\alpha_1)}{\Delta t},\ M^e = -\frac{\alpha_0}{\alpha_1},\ \sigma = \varphi\left(\frac{2\log(1+\alpha_1)}{\alpha_1(2+\alpha_1)\Delta t}\right)^{1/2}$$

$\Delta t = 1$ because our data are yearly. The normalized estimates of the required parameters in equation (2) are therefore α = 0.384, M^e= 1.317 and σ = 0.256. These parameters imply that in the long run the gross processing margin in the corn ethanol industry is normally distributed with mean \$1.317/gallon and the standard deviation $\sigma/\sqrt{2\alpha}$ = 0.292. The implied half-life of shocks to the margin is log2/ α=0.783 years, or 9.4 months. This means that half of each shock to the margin is expected to have faded away after 9.4 months.

In addition, the model needs the estimates of four other parameters: *r*, *h*, *c* and *k*. *r* is the CAPM risk-adjusted rate of return in the ethanol industry and the industry average is about 12%. *h* is the investment lag and the industry average is approximately 3 years. The marginal variable cost parameter *c* is \$1.32/gallon. *k* is the capital investment cost for each additional gallon of capacity, and the historical average is \$1.52/gallon.

We calculated the optimal industry capacity levels during 1999 and 2010. Table 2 shows the comparisons between the optimal capacities derived from the real options model and the observed capacities.

Table 2. Real Capacity vs. Optimal Capacity (Million Gallons)

Year	Real Capacity	Optimal Capacity
1999	1701.7	1704.8
2000	1748.7	1752.4
2001	1921.9	1925.8
2002	2347.3	2352.1
2003	2706.8	2712.2
2004	3100.8	3106.9
2005	3643.7	3651.1
2006	4336.4	4345.2
2007	5493.4	5354.7
2008	7888.4	7773.9
2009	10569.4	10591.6
2010	11877.4	11901.1

As shown in Table 2, most years have seen the real capacity numbers fairly close to the optimal real options capacity values. However, during 2007 and 2008, the real capacity numbers are more than the optimal capacity levels suggested by the real options model. This could be due to the fact that the gross processing margin hit the record high in 2006 and the capacity expansion lasted a couple of years since 2006. The industry might have been too optimistic about the market profitability and become aggressive in building up its capacity. It led to overcapacity in the later years which in turn reduced the processing margin.

Furthermore, we conducted the sensitivity analyses for the major parameters that influence the optimal capacity values. The results show that the processing margin uncertainty σ contributes the most to the optimal capacity value, followed by the processing margin mean M^e, the investment cost *k*, the unit marginal variable cost *c*, and the investment lag *h*. Specifically, a 1% increase in σ could decrease the optimal capacity by 0.1%. During the years when market uncertainty is high, it seems that σ has a dominant role in determining the optimal capacity through the option value. In addition, a 1% increase in the processing margin mean could increase the derived optimal capacity by 0.06%. And a 1% increase in the investment cost *k*, the unit marginal variable cost *c* and the investment lag *h* decreased the optimal industry capacity by 0.02%, 0.01% and 0.007%, respectively. Since these elasticity terms for optimal capacity are highly inelastic, the values in Table 2 are rather robust.

Conclusions

During the mid-2000s, the U.S. ethanol industry saw rapid growth and capacity expansion due to the high industry profitability before 2008. The feasibility studies on ethanol industry capacity in the literature have mainly used traditional DCF methods such as NPV and IRR. This study applies the real options approach to derive the optimal U.S. corn ethanol capacities from 1999 to 2010. The impact of market uncertainty on the capacity investment decision was examined under the assumption that the gross processing margin follows a stochastic process characterized by mean-reverting geometric Brownian motion. We find that the expansions in 2007 and 2008 might not have been recommended by the real options model because the industry might have been too optimistic about the market profitability. The real options approach properly incorporated the value of waiting to invest irreversibly. It could serve as an important mechanism to prevent business planners from being overly aggressive when there is high market uncertainty.

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