Ethanol Plant Investment Under Uncertainty – A Real Options Analysis

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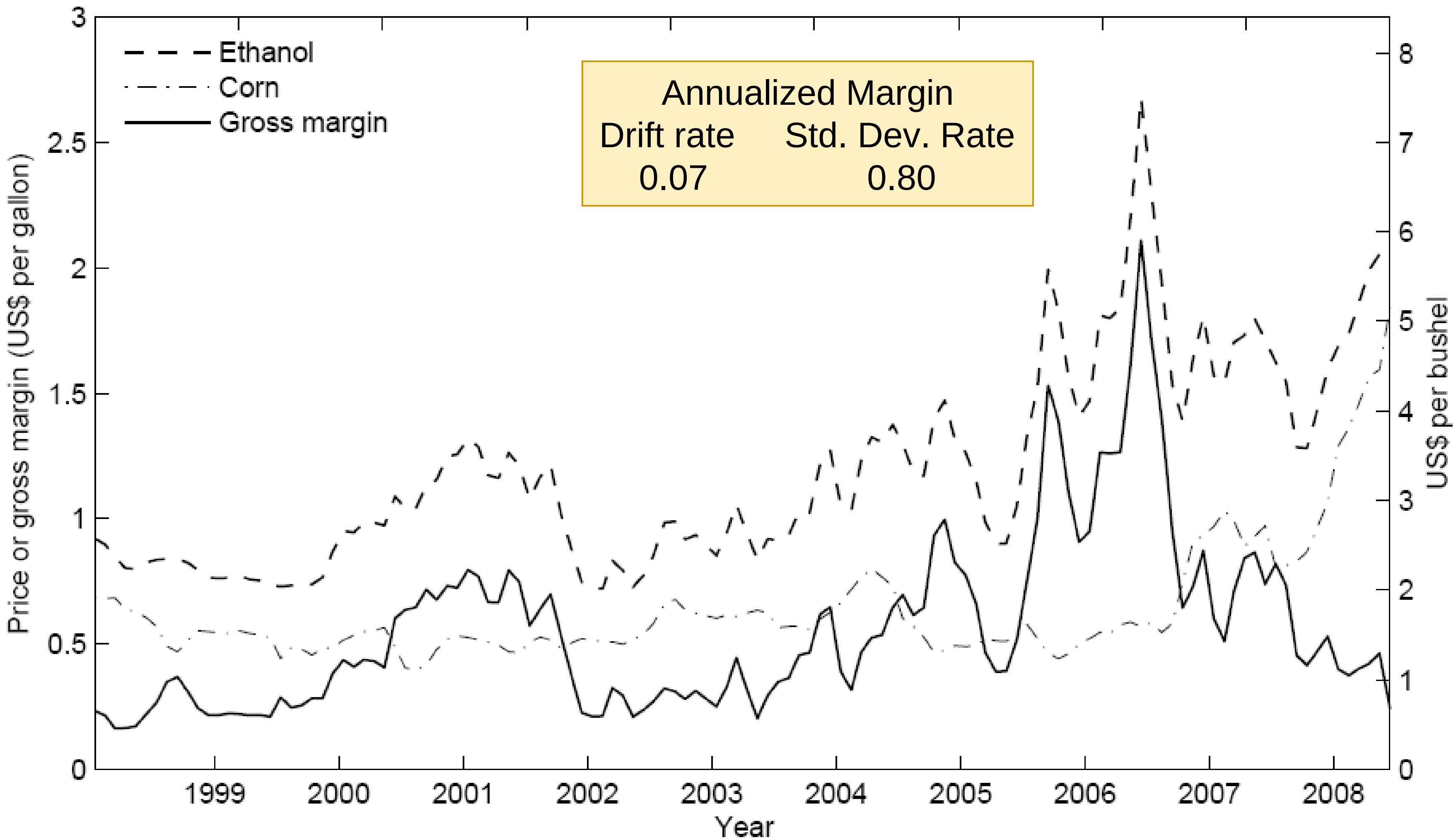
Introduction & Objectives

- Rapidly changing market conditions have implications for biofuels investment decisions and operations
  - Strong demands for ethanol *fueled* by high energy prices and policy changes resulted in strong returns and rapid industry expansion.
  - Waning energy prices relative to commodity inputs, shifts in policy, and satisfaction of blending demands precipitously reduced marketing margins and stalled investments.
  - The result is a volatile market from which to make investment decisions. What does this volatility imply for changes in management decisions and industry development?

- Objectives
  - Use a real options framework to directly consider margin volatility and its implication for optimal entry-exit decisions of corn-based ethanol plants.
  - Include intermediary decisions by firms to mothball (shutter) and reactivate plants.
  - Understand how these decisions vary by plant size
  - Provide implications of the model/results to firm and policy audiences

Ethanol Prices and Gross Margins



Source: Bloomberg, Datastream Int'l.

The real options approach…

- Financial option theory applied to physical assets: entry and exits by firms are modeled as call and put options with the plant owner as the holder (buyer) of these options. These options have value, such that when considering uncertainty:
  - A firm may be reluctant to make an investment because not making that investment preserves the option of making a better investment later; while an existing firm may be reluctant to exit because not exiting it holds the option of keeping the operation going until market conditions improve.
  - The options will not be exercised until the discounted losses or discounted profits exceed the value of the exit and entry option values, thus causing the zone of inactivity to widen relative to NPV.
  - Intermediary decisions to mothball and reactivate have option values as well.
  - Existence of price variability, along with fixed costs to enter, exit, mothball, and reactivate produces option value; i.e., option value does not require risk aversion.

- Real options has been used in other agricultural investment evaluations, but little applied in bioenergy/biofuels area.
  - Most literature are deterministic framework with sensitivity analysis; e.g., break-even analysis, NPV
  - Some incorporation of uncertainty via stochastic simulation with various price scenarios, but generally consider plant investment as given
  - Recent exceptions: methane digesters (Stokes, Rajagopulan, Stefanou 2008), ethanol plants with discrete time horizon (Zou and Pederson 2008)

Model framework:

Nomenclature:

k = investment cost
w = operating cost
l = exit cost
δ = discount rate
μ = drift parameter of P
E_m = mothballing cost
m = maintenance cost
r = reactivation cost
P = ethanol gross margin
σ = std. dev. parameter of P

P is stochastic:

$dP = \mu P dt + \sigma P dz$ (GBM)

$dz = \varepsilon (dt)^{0.5}$ $\varepsilon \sim N(0,1)$

Determine trigger prices:

P_h	>	P_r	>	W_h	>	W_l	>	P_m	>	P_l
Entry		Reactivate		$w + \delta k$		$w - \delta l$		Mothball		Exit

Value functions (discounted expected values):

Idle: $V_0(P) = B_0 P^{\beta}$

Active: $V_1(P) = P/(\delta - \mu) - w/\delta + A_1 P^{-\alpha}$

Mothballed: $V_m(P) = A_m P^{-\alpha} + B_m P^{\beta} - m/\delta$

$\beta = \beta(\mu, \sigma, \delta) > 1$, $-\alpha = -\alpha(\mu, \sigma, \delta) < 0$

Conditions to satisfy:

Value Matching:

1) $V_0(P_h) = V_1(P_h) - k$
2) $V_1(P_m) = V_m(P_m) - E_m$
3) $V_m(P_r) = V_1(P_r) - r$
4) $V_m(P_l) = V_0(P_l) - l$

Smooth Pasting:

5) $V'_0(P_h) = V'_1(P_h)$
6) $V'_1(P_m) = V'_m(P_m)$
7) $V'_m(P_r) = V'_1(P_r)$
8) $V'_m(P_l) = V'_0(P_l)$

8 equations
8 unknowns ($A_1, B_0, A_m, B_m, P_h, P_r, P_m, P_l$)
Solve for using numerical approaches

Investment and cost parameters by plant size

Estimated baseline dry-grind corn ethanol investment and operating costs from available literature, ($/gal).

Plant Size	Invest (k)	Exit (l)	Co-Product	Operating Costs: Full (w)	Operating Costs: Net (w')	Mothball Costs: Invest (E_m)	Mothball Costs: Maint. (m)	Mothball Costs: React. (r)
Small	1.95	-0.49	0.35	0.74	0.40	0.10	0.05	0.20
Medium	1.39	-0.35	0.34	0.69	0.35	0.07	0.03	0.14
Large	1.22	-0.31	0.34	0.70	0.36	0.06	0.03	0.12

Note: Baseline costs assume exit cost (l) = -0.25k, investment mothball cost (E_m) = 0.05k, maintenance mothball costs (m) = 0.025k, and reactivation cost (r) = 0.10k. Operating costs exclude corn feedstock costs.

$0.70/gal operating costs equivalent to $1.96/bu corn (2.8 gal/bu conversion ratio)
Small: < 25 mgy, Medium: 25-75 mgy; Large: >75 mgy

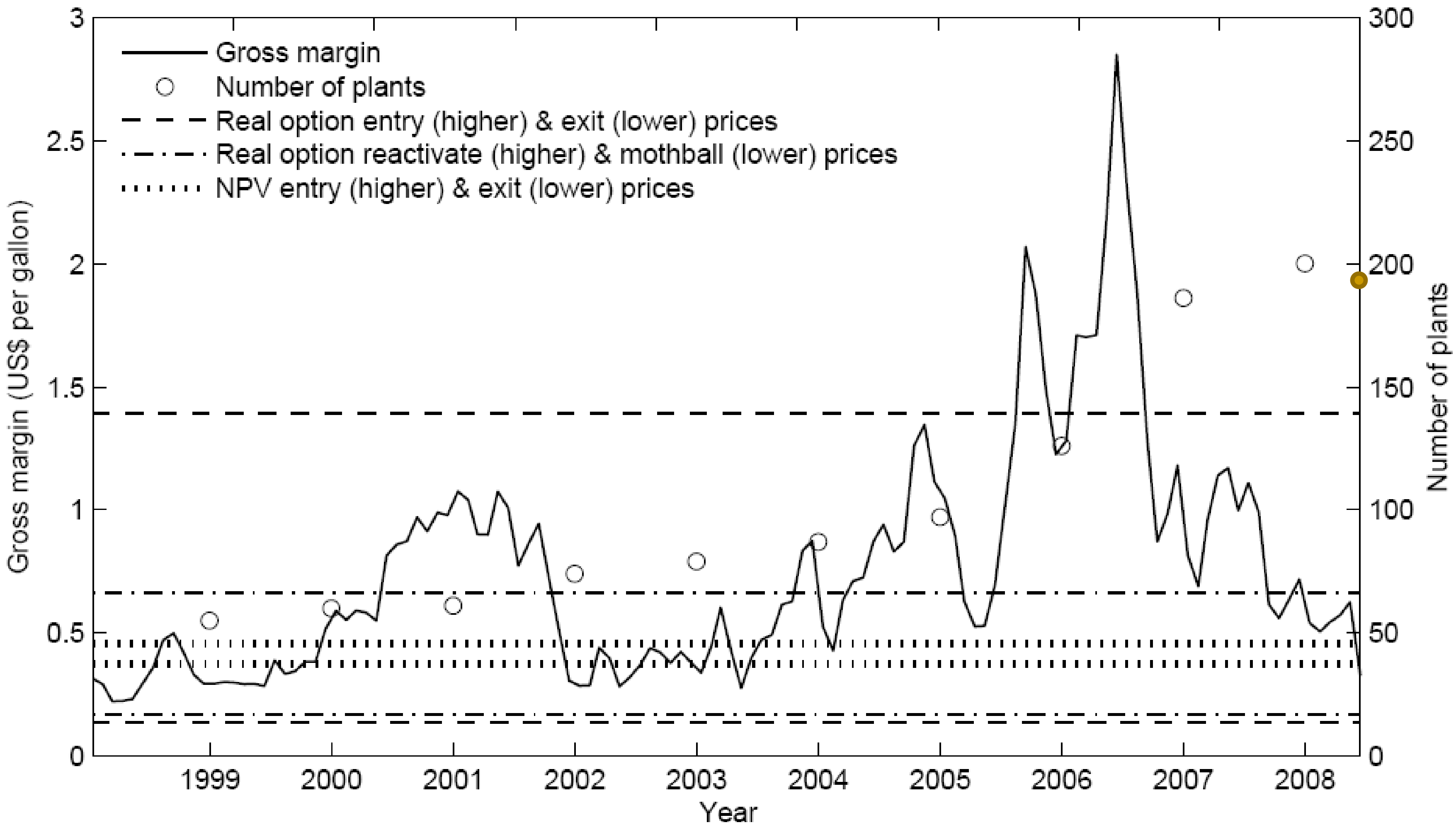
Estimated margin triggers by plant size

Gross margin trigger prices using NPV and real option analyses.

Cost or Trigger Price	Plant Size		
	Small	Medium	Large
Investment Cost (k)	1.95	1.39	1.22
Net Operating cost (w')	0.40	0.35	0.36
Entry, P_h	1.78	1.39	1.33
Reactivate, P_r	0.79	0.66	0.66
Entry (NPV), W_h	0.55	0.46	0.45
Exit (NPV), W_l	0.43	0.37	0.38
Mothball, P_m	0.18	0.17	0.18
Exit, P_l	0.17	0.14	0.13

Note: NPV = Net Present Value, exit cost (l) = -0.25k, investment mothball cost (E_m) = 0.05k, maintenance mothball costs (m) = 0.025k, and reactivation cost (r) = 0.10k. Net operating costs exclude corn feedstock costs.

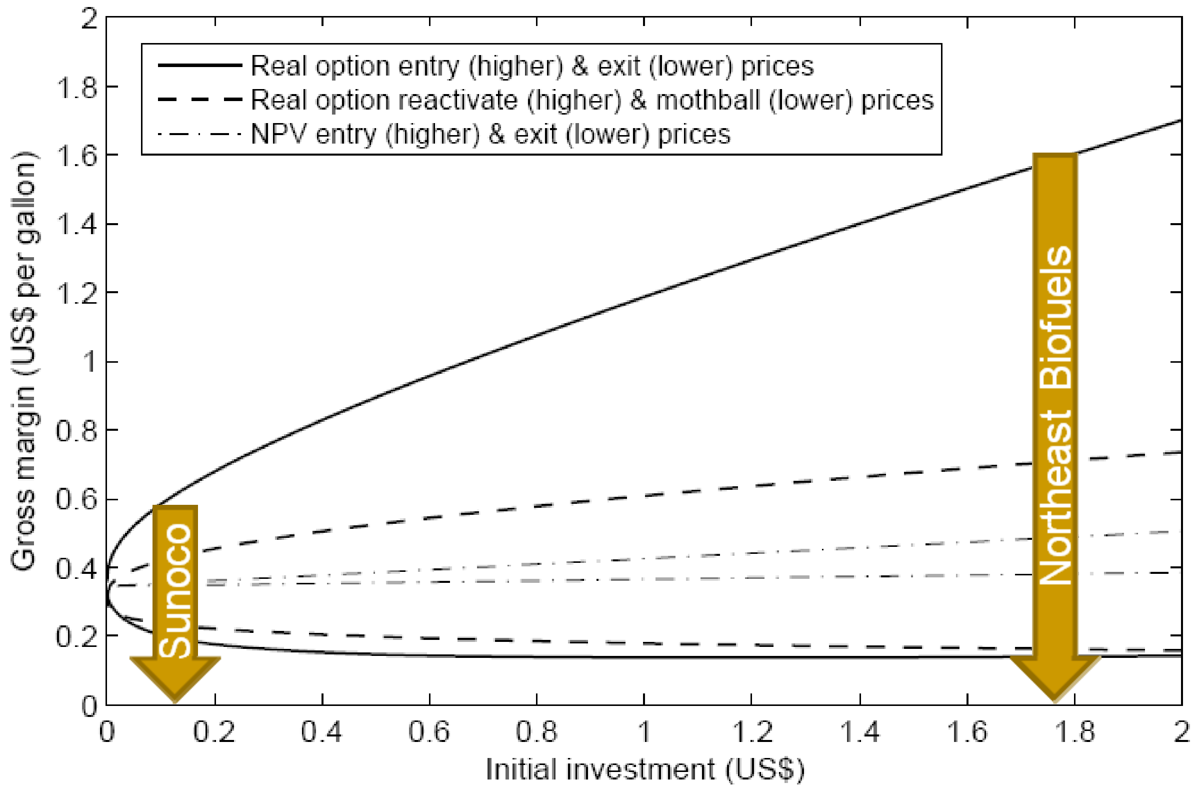
Trigger prices relative to historical data



Number of plants includes operating plants and plants under construction (RFA).

Capital investment costs and current conditions

- Model generally assumes decisions made by "first owners"; i.e. enter and build plant.
- Current adversity has resulted in rewriting of asset values and transfer of ownership. Plant exit doesn't occur, but the underlying cost parameters are changed dramatically.



<u>Northeast Biofuels, Volney, NY</u>

- **114 mgy plant, 2006-construction, limited production began 8/08**
- **$200M capital cost or $1.75/gal (retrofitted brewery)**
- **Design problems, never reached full capacity**
- **Bankruptcy filing Jan 2009**
- **May 2009 - Sunoco purchases to integrate NEB with refinery operations in the NE**
- **Sales Price: $8.5M + $11M expected fix cost → $0.17/gal**

Conclusions, implications, directions

- Consideration of price volatility is a necessary and important consideration for management decisions and policy considerations
  - Real options entry (exit) margin triggers were 207% (63%) above (below) NPV triggers
  - Model results are consistent with historical experience (using baseline parameters)
  - Plant size matters – given economies of size, larger firms will get in sooner and get out later.
  - Increasing volatility raises (lowers) entry and reactivate (mothball and exit) triggers
- Useful applications:
  - The modeling approach can be adapted by individual firms with firm-specific data and pricing strategies as a tool for improved decision-making.
  - As policy impacts prices, alternative policies can be evaluated in terms of relative price effects and implications for industry development, including alternative biofuels investments
- Further direction:
  - Incorporation of additional (separate) stochastic variables (e.g., corn, ethanol, DDGS) and forms of behavior (e.g., mean-reverting)
  - Directly incorporating policy variables and uncertainty surrounding them (e.g., jump processes)
  - Consideration of time effect from investment to production (not instantaneous)
  - Does the form of plant ownership matter (e.g., investors, farmers, refiners)?

Thank You!

Schmit, T.M., J. Luo, and L.W. Tauer. 2008. “Ethanol Plant Investment using Net Present Value and Real Options Analyses.” WP 2008-14, Department of Applied Economics and Management, Cornell University.

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