Impact of Volatility in Bioenergy Investments: A Real Options Approach

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Motivation

- Growing importance of bioenergy in the total energy mix ⇨ *thrust to invest in bioenergy*
- Bioenergy production still not cost-efficient ⇨ *significant (but temporal) political promotion*
- Increasing linkage between the energy and food market ⇨ *additional volatility sources*
- Bioenergy investments ⇨ *cost-intensive, irreversible investments under uncertainty*

Objective of the study

- While the impact of bioenergy promotion on food prices and supply attracted much research effort, the simultaneous effect of the output and input market uncertainties on bioenergy investments (especially in the absence of policy support) is less studied.

⇨ **Modeling the impact of**

(1) multiple uncertainties and

(2) option to suspend (loss reduction in bad states + chance for high profits in good states)

on irreversible investment decisions of bioenergy producers

Model

- Modeling investment decisions of bioenergy producers under uncertainty
- Partial equilibrium model of energy, bioenergy and food markets

Energy market (global)	Bioenergy market (local)	Food market (local)
– represented by exogenous electricity price (as a proxy for the global energy price) – energy price follows a geometric Brownian motion (GBM) – energy and corn demand are correlated due to economic growth	– aggregated producer – irreversible investments with option to suspend production – unlimited demand (food market small compared to energy market) – supply is limited by production capacity in short term – no policy support program	– aggregated producer – limited exogenous corn supply – corn is demanded by bioenergy sector and food market – stochastic shocks to food demand (follows GBM) – corn for food dependent on energy price

- **Base scenario:** time step=1 period, time lag=1 period, initial variable to fixed cost ratio=15
- **Modification:** one uncertainty, four different time lags and variable to fixed cost ratios
- Investment trigger (the critical price at which it is optimal to invest) is normalized to the total investment cost per unit of output

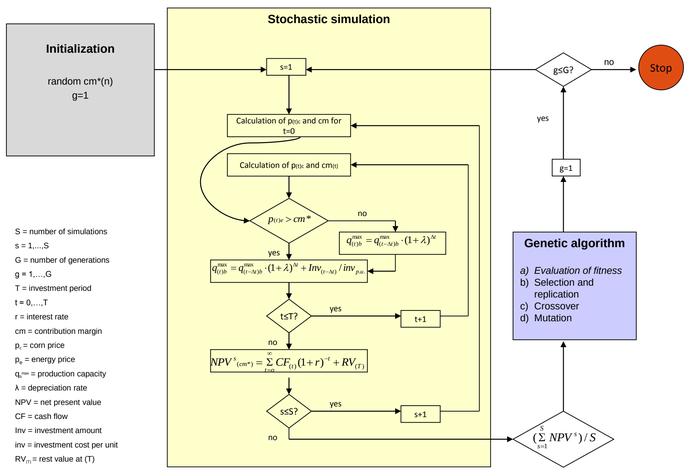
Methodology

- Real options approach ⇨ Investment rule: *Net present value of expected returns should cover not only the present value of investment outlays, but also the discounted value of managerial flexibility*
- Stochastic simulations in combination with genetic algorithm technique

⇨ **Simulation of the equilibrium investment trigger under variation of:**

- volatility of food demand (σ_φ)
- volatility of energy price (σ_e)
- variable to fixed cost ratio (VC/FC)
- time lag (TL)
- food demand parameter (φ)
- asset depreciation rate (λ)
- food demand elasticity (η)
- degree of correlation of both stochastic processes (α)

Flow chart of stochastic simulation



S = number of simulations
s = 1,…,S
G = number of generations
g = 1,…,G
T = investment period
t = 0,…,T
r = interest rate
cm = contribution margin
p_t = corn price
p_e = energy price
q_t^{max} = production capacity
λ = depreciation rate
NPV = net present value
CF = cash flow
Inv = investment amount
inv = investment cost per unit
$RV_{(T)}$ = rest value at (T)

Results

- The possibility to temporally limit losses through production suspension may create incentives to invest even at high uncertainty
- Such negative response is true in the presence of both single and multiple uncertainty sources
- At very high volatilities the trigger may decline below investment cost
- The more the energy and food markets get correlated the more unpredictable the impact of rising volatility on the optimal investment rule might be

Table 1: Investment trigger under variation of σ_φ and σ_e (Δt=1, TL=1, VC/FC≈15)

[a] α = 0

volatility of energy price, σ_e	volatility of food demand parameter, σ_φ 0%	2.5%	5%	10%	20%
0%	1.0000	1.1711	1.2769	0.9915	0.7888
2.5%	1.1410	1.2503	1.3173	0.9645	0.7386
5%	1.2814	1.3298	*1.2915*	0.9037	0.7316
10%	*1.2471*	*1.2060*	*1.0536*	0.7732	0.6556
20%	0.8745	0.7299	0.7041	0.6667	0.5692
30%	0.6822	0.6626	0.6412	0.5740	0.4642

[b] α = 0.5

volatility of energy price, σ_e	volatility of food demand parameter, σ_φ 0%	2.5%	5%	10%	20%
0%	1.0000	1.0681	1.2027	1.1210	0.8364
2.5%	1.0522	1.0764	1.1825	1.1499	0.7396
5%	1.2357	1.1839	1.2440	1.1846	0.8006
10%	1.4546	1.4756	1.4413	1.2879	0.6638
20%	1.7548	1.8162	1.8473	1.6544	0.9199
30%	1.8689	1.9273	1.9706	2.0569	*1.1765*

[c] α = 1

volatility of energy price, σ_e	volatility of food demand parameter, σ_φ 0%	2.5%	5%	10%	20%
0%	1.0000	1.1604	1.2715	0.9939	0.7793
2.5%	1.1471	1.0099	1.2455	*1.1867*	0.7513
5%	1.2891	1.0702	1.0734	1.2578	0.7078
10%	*1.2304*	1.4372	*1.3117*	*1.2035*	0.8972
20%	0.7648	0.7397	0.8248	1.7319	*1.2858*
30%	0.7494	0.6368	0.6243	0.5647	2.2917

standard positive response to increasing uncertainty;
negative response to increasing uncertainty;
strong negative response to increasing uncertainty (trigger below investment cost)

Results

- Introducing time lags and the option to suspend may not only reduce, but also overcompensate the depressive effect of uncertainty on investments
- Explanation: for high volatilities the downside risk is limited, while a chance for very high profits exists if returns increase due to positive shocks
- This effect is stronger for longer lags and disproportionally high variable costs
- These results contradict the conventional investment theory (Dixit/Pindyck, 1994), but support findings of e.g. Bar-Ilan/Strange (1996) and Maoz (2008)

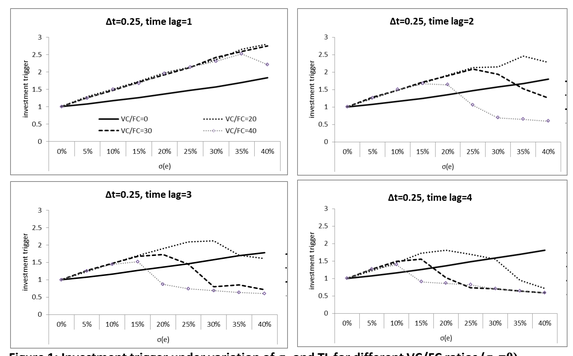


Figure 1: Investment trigger under variation of σ_e and TL for different VC/FC ratios (σ_φ=0)

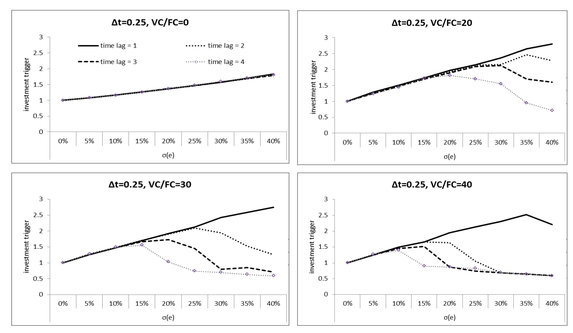


Figure 2: Investment trigger for TL= 4 periods under variation of σ_e and VC/FC (σ_φ=0)

Conclusions

- The positive correlation between volatility and investment trigger does not always hold for real investment
  - this could be observed for a single uncertainty and multiple uncertainty sources
- Possibility to reduce losses through temporary production suspension may increase investment incentives even at high volatilities
  - particularly n the presence of long investment lags and disproportionally high variable costs
- Implications for:
  - firms with high variable to fixed cost ratio and time to build
  - macroeconomic policy decisions aiming at risk reduction

Further Research

...is needed

- to analytically show the impact of multiple volatilities and of the option to suspend
- to study the effect of the phasing out of policy support regimes on the optimal investment rule under growing uncertainty
- to study the effect of growing uncertainty and of the option to suspend on investment decisions in a competitive environment

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