Does Uncertainty Matter?
A Competing Risks Analysis of Investment in Petroleum Refining Industry

Xiaoyi Mu
xiaoyimu@ou.edu

25th Annual North American Conference
USAEE/IAEE
Outline

- Introduction
- Investment in the Refining Industry
- Measuring Uncertainty
- The Competing Risks Framework and Empirical Findings
- Conclusion
The only thing certain is that uncertainty will remain.
Introduction

- **Energy Economics Examples**
  - When natural gas price increases, drilling activity may not follow.
  - When refining margin rises, investment in the refining industry may not increase (as it is NOW).

- **Policy Implications**
  - The effectiveness of policies designed to influence investment may be affected by uncertainty.
Introduction

- A hot debate in the literature
- Theories have contradictory predictions
  - Positive
  - Negative
    McDonald & Siegel (1986), Pindyck (1988), Dixit and Pindyck (1994)
  - Positive for perfect competition, negative for oligopoly. Caballero (1991)
Introduction

- Empirical evidence
  - General consensus using macro data
  - Less conclusive using micro data

- Two challenges to empiricists
  - How should uncertainty be captured?
  - How should the economic value of capital and investment be measured?
Introduction

- Accounting data rarely allows a researcher to correctly measure the economic value of capital.
  - Economic depreciation rate
  - Many investments are for replacement

“The empirical investment literature is full of disappointments. … There are at least as complex, and perhaps insurmountable data problems. Both right- and left-hand side variables are seldom measured properly.”

---- Caballero, Engle and Haltiwanger (1995)
Introduction

- This paper confronts these problems by studying investment in the refining industry.
  - Construct uncertainty measures from forward refining margins
  - Use capacity change to measure investment rather than relying on account data
Fraction of Investment

Fraction of Investment

Disinvestment

Investment

Disinvestment
Total number of observations (refinery-year): 3324.
The far left bar (-1) represents complete shut-down refineries.
Distribution of Durations between Two Capacity Changes

Duration1: Years of duration between two capacity changes with zero threshold. Duration2: Years of duration between two capacity changes with 5% threshold.
Measuring Uncertainty

- Uncertainty is subject to investors’ mental judgment about the distribution of future returns.
  - Forward-looking
  - Corresponds to future profitability
  - Subjective

- We construct uncertainty measures from forward refining margins.
  - Ma (1989): On average futures markets outperform econometric (time series) models for all the three petroleum commodities.
  - Fujihara and Mougoue (1997): Petroleum futures markets are weak form efficient.
Measuring Uncertainty

- **Daily forward refining margin**

\[ FRM_t = 2 \times F_{GO}^{T,t} + 1 \times F_{HO}^{T,t-3} + 3 \times F_{CO}^{T,t} \]

Daily close price of NYMEX with 6 months maturity

- **Annual Margin**

\[ Margin = \frac{\sum_{i=1}^{N} FRM_i}{N} \]

and \( Uncertainty = \sqrt{\frac{\sum_{n=1}^{N} (FRM_i - Margin)^2}{N-1}} \)

Where \( N \) is the number of trading days in a year.
Forward Refining Margin and Uncertainty Measure
The Competing Risks Framework

- Focus on the effect of uncertainty on the timing of investment.

- Hazard: the conditional probability that a refinery will invest or disinvest given it stays in inaction until $t$
  - Survival variable: Duration of a refinery staying in inaction
  - Two competing risks: investment and disinvestment
  - Proportional hazard
  - Shared frailty

$$\lambda(t, x, \beta, \lambda_0) = \exp(x' \beta)\lambda_0(t)\nu$$
The Competing Risks Framework

- Baseline hazard: Weibull $\lambda_0(t) = \rho t^{\rho-1}$
  - $\rho > 1$, positive duration dependence.
  - $\rho = 1$, constant hazard, no duration dependence.
  - $\rho < 1$, negative duration dependence.

- Other control variables
  - Capacity utilization rate
  - Ownership change
  - Dummy for small refineries
## Estimation Result with 5% Threshold

<table>
<thead>
<tr>
<th></th>
<th>Investment</th>
<th>Disinvestment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Margin1</strong></td>
<td>0.187* (0.104)</td>
<td>-0.192 (0.148)</td>
</tr>
<tr>
<td><strong>Uncertainty1</strong></td>
<td>-0.543*** (0.207)</td>
<td>-0.707** (0.354)</td>
</tr>
<tr>
<td><strong>Urate</strong></td>
<td>-0.012 (0.010)</td>
<td>-0.069*** (0.016)</td>
</tr>
<tr>
<td><strong>Ownchg</strong></td>
<td>-0.036 (0.205)</td>
<td>0.007 (0.331)</td>
</tr>
<tr>
<td><strong>Small</strong></td>
<td>-0.406*** (0.157)</td>
<td>2.248*** (0.299)</td>
</tr>
<tr>
<td>(\rho) (H0: (\rho=1))</td>
<td>1.187*** (0.060)</td>
<td>1.505*** (0.116)</td>
</tr>
<tr>
<td>LR test (H0: (\theta=0))</td>
<td>16.65***</td>
<td>12.03***</td>
</tr>
<tr>
<td><strong>No of spells</strong></td>
<td>546</td>
<td>288</td>
</tr>
<tr>
<td><strong>Log likelihood</strong></td>
<td>-694.48</td>
<td>-319.68</td>
</tr>
</tbody>
</table>
## Estimation Result with 5% Threshold

<table>
<thead>
<tr>
<th></th>
<th>Investment</th>
<th>Disinvestment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Margin2</strong></td>
<td>0.267*** (0.102)</td>
<td>0.025 (0.143)</td>
</tr>
<tr>
<td><strong>Uncertainty2</strong></td>
<td>-0.822*** (0.266)</td>
<td>-0.679* (0.411)</td>
</tr>
<tr>
<td><strong>Urate</strong></td>
<td>-0.011 (0.010)</td>
<td>-0.067*** (0.016)</td>
</tr>
<tr>
<td><strong>Ownchg</strong></td>
<td>-0.064 (0.205)</td>
<td>-0.030 (0.331)</td>
</tr>
<tr>
<td><strong>Small</strong></td>
<td>-0.412*** (0.159)</td>
<td>2.312*** (0.303)</td>
</tr>
<tr>
<td>( \rho ) ((H_0: \rho=1))</td>
<td>1.209** (0.060)</td>
<td>1.521*** (0.113)</td>
</tr>
<tr>
<td>LR test ((H_0: \theta=0))</td>
<td>18.23***</td>
<td>13.68***</td>
</tr>
<tr>
<td>No. of spells</td>
<td>546</td>
<td>288</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-692.91</td>
<td>-322.00</td>
</tr>
</tbody>
</table>
### Estimation Result with 5% Threshold

<table>
<thead>
<tr>
<th></th>
<th>Investment</th>
<th>Disinvestment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2$</td>
<td>0.268***</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>(0.102)</td>
<td>(0.143)</td>
</tr>
<tr>
<td>Uncertainty2</td>
<td>-0.695**</td>
<td>-1.351***</td>
</tr>
<tr>
<td></td>
<td>(0.277)</td>
<td>(0.461)</td>
</tr>
<tr>
<td>Urate</td>
<td>-0.012</td>
<td>-0.066***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Ownchg</td>
<td>-0.082</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>(0.205)</td>
<td>(0.333)</td>
</tr>
<tr>
<td>Small</td>
<td>-0.488***</td>
<td>2.732***</td>
</tr>
<tr>
<td></td>
<td>(-2.92)</td>
<td>(0.326)</td>
</tr>
<tr>
<td>Integ*Uncertainty2</td>
<td>-0.359</td>
<td>1.687***</td>
</tr>
<tr>
<td></td>
<td>(0.244)</td>
<td>(0.390)</td>
</tr>
<tr>
<td>$\rho$ ($H_0: \rho=1$)</td>
<td>1.211***</td>
<td>1.530***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.113)</td>
</tr>
<tr>
<td></td>
<td>17.54***</td>
<td>13.20***</td>
</tr>
</tbody>
</table>
Conclusion

- Uncertainty measures have a significantly negative impact on refiners decision to invest.
  - Robust to investment thresholds and uncertainty measures.
  - Support theories emphasizing irreversibility.

Main contributions

- Uncertainty measures
  - Constructed from forward market
  - Reflects uncertainties in both I/O prices
- Capacity changes to measure investment episodes.
- Investment episodes are lumpy, supportive of non-convex costs of K adjustment.