Estimating regulatory distortions of natural gas pipeline investment incentives

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SVEC
Introduction

- Interstate natural gas pipelines in US
  - Regulated price of transmission set by rate-of-return
  - Investment must be approved by regulator (FERC)
- How do the investment incentives faced by pipelines compare to the marginal value of investment?
- Estimate pipelines’ perceived marginal value of investment from Euler equations
- Use differences in prices between trading hubs on pipeline network to measure marginal social value of investment
Natural gas is large and growing
Suggestive evidence of over-investment

- Rate-of-return regulation – Averch-Johnson effect
  - Pipeline owners can raise their prices by increasing capital costs
- Rate of return allowed by FERC is high
- FERC approves nearly all pipeline expansion projects – only two rejected application between 1996 and 2016
Suggestive evidence of under-investment

- Prices of natural gas at different locations sometime diverge
- Gas marketers, not pipeline owners, earn profits from arbitrage
Daily natural gas prices
Contributions

- Construct a detailed pipeline dataset from FERC and EIA filings
- Estimate pipelines’ investment costs (including regulatory costs) from Euler Equations
  - Nonparametrically identified
  - Simple to estimate
  - Key assumption: information set of pipeline is observed or estimable
- Examine relationship between investment cost and pipeline network bottlenecks
- Areas of pipeline congestion have:
  - Lower regulatory marginal investment cost
  - Lower expected marginal product of capital
Natural gas from production to consumption

1. Production at well-head
2. Gas purchased at well-head by marketer
3. Marketer pays pipeline to transport gas
4. Gas sold to :
   ▶ Other marketer at hub
   ▶ Local distribution company
   ▶ Power plant or large industrial user
5. Local distribution company delivers gas to industrial and residential consumers
Contracts between pipelines and marketers

- Long term (average 9.1 years) contracts for firm transportation service
  - Guaranteed right to transport a specified volume of gas along a pipeline per day
  - Large reservation charge
    ★ Set by FERC using rate of return to cover capital costs
  - Small additional charge per unit used
    ★ Set by FERC to cover marginal operating cost
- Unused capacity sold as interruptible transportation service
  - Price ≤ reservation + utilization price of FTS
  - Open access short term auctions through online bulletin boards
Building or expanding a pipeline

1. Obtain binding agreements from gas marketers to purchase 5-10 year FTS contracts for 80+% of planned capacity
2. File application with FERC
3. Public hearings, environmental assessments, etc
4. FERC approves 99% of applications

- Takes 1-3 years for new pipelines, much less for smaller projects
- Decommissioning and sales also need to be approved
- Streamlined for small projects
  - Automatic (<$11,400,000) notify landowners 45 days in advance
  - Prior notice (<$32,400,000) file plan with FERC, automatically approved after 60 days if no objection
Investment model

- Pipeline \( j \) choosing investment at time \( t \)
- Bellman equation:

\[
\begin{align*}
v(\kappa_{jt}, \chi_{jt}) = & \max_{i_{jt}} \pi(\kappa_{jt}, \chi_{jt}) - i_{jt}(1 + \eta_{jt}) - c(\kappa_{jt}, i_{jt}) + \\
& + \beta E \left[ v(\kappa_{jt} + i_{jt}, \chi_{jt+1})|I_{jt} \right]
\end{align*}
\]

where

- \( \kappa_{jt} \) = capital
- \( i_{jt} \) = dollars of investment
- \( \pi \) = variable profit function
- \( \chi_{jt} \) = vector of observed and unobserved variables affecting profits, e.g. \( k_{-jt} \), details of pipeline network, gas reserves and discoveries
- \( c(k, i) \) = cost of obtaining FERC approval
- \( \eta_{jt} \) = investment cost shock
- \( \beta \) = discount factor
- \( I_{jt} \) = information set of pipeline \( j \) at time \( t \)
Bellman equation:

\[ v(k_{jt}, x_{jt}) = \max_{i_{jt}} \pi(k_{jt}, x_{jt}) - i_{jt}(1 + \eta_{jt}) - c(k_{jt}, i_{jt}) + \beta E \left[ v(k_{jt} + i_{jt}, x_{jt+1}) | J_{jt} \right] \]

First order condition and envelope theorem gives Euler equation:

\[ 1 + \eta_{jt} + \frac{\partial c}{\partial i}(k_{jt}, i_{jt}) = \beta E \left[ \frac{\partial \pi}{\partial k}(k_{jt+1}, x_{jt+1}) - \frac{\partial c}{\partial k}(k_{jt+1}, i_{jt+1}) + 1 + \eta_{jt+1} + \frac{\partial c}{\partial i}(k_{jt+1}, i_{jt+1}) | J_{jt} \right] \]
Identification of $c(k, i)$

- **Key simplification**: $\pi_{jt} = \pi(k_{jt}, x_{jt})$ is observed and $k_{jt+1} = k_{jt} + i_{jt} \in J_{jt}$ so

$$E \left[ \frac{\partial \pi}{\partial k}(k_{jt+1}, x_{jt+1})|J_{jt} \right] = \frac{\partial}{\partial k} E \left[ \pi_{jt+1}|J_{jt} \right]$$

- **Assumptions**
  1. $\beta$ is known
  2. $E[\cdot|J_{jt}]$ is identified (e.g. $J_{jt}$ is observed)
  3. Boundary condition : $c(k, 0) = 0 \ \forall k$

- Then $c(k, i)$ is identified
Pipeline data

- FERC Form 2/2a annual data on pipeline companies
  - 1996-2016
  - 96-123 companies each year
  - detailed information about revenue, expenses, capital, transmission volume, etc
  - limited information about pipeline locations and connections

- EIA form 176 has information on each pipelines’ mileage and flow within each state and capacities between states
  - 1997-2015
  - merged with FERC data by company name — 3% of pipeline mileage unmatched
Evolution of capital

Pipeline investment

Data
Distribution of investment

Pipeline investment

Data
Schematic pipeline network in 1996
Schematic pipeline network in 2001
Schematic pipeline network in 2006
Schematic pipeline network in 2011
Schematic pipeline network in 2016
Empirical specification

- Information set, $J_{jt} =$
  - capital, dekatherms of gas transmitted
  - total of pipelines that operate in the same states capital and transmission
  - year dummies

- $\frac{\partial}{\partial k} E[\pi_{t+1} | J_t]$ estimated by regression with all linear terms and second order terms involving capital

- Regulatory cost assumed to be either linear or quadratic

- Instruments = $J_{jt-1}$
Linear regulatory cost

- Linear regulatory cost: \( c(k, i) = c_i i \)
- Euler equation

\[
(1 + c_i)(1 - \beta) + \eta_t = \beta \frac{\partial}{\partial k} E[\pi_{t+1}|J_t]
\]

- Estimator

\[
\hat{c}_i = \frac{\beta}{1 - \beta} \frac{\partial}{\partial k} E[\pi_{t+1}|J_t] - 1
\]
## Results: linear regulatory cost

\[ \frac{\partial}{\partial k} E[\pi_{t+1}|J_t] \]

<table>
<thead>
<tr>
<th>( \beta ) (fixed)</th>
<th>0.90</th>
<th>0.91</th>
<th>0.92</th>
<th>0.93</th>
<th>0.94</th>
<th>0.95</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \hat{c}_i )</td>
<td>-0.12</td>
<td>-0.01</td>
<td>0.12</td>
<td>0.29</td>
<td>0.53</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.12)</td>
<td>(0.14)</td>
<td>(0.16)</td>
<td>(0.19)</td>
<td>(0.24)</td>
</tr>
</tbody>
</table>

\( \frac{\partial}{\partial k} E[\pi_{t+1}|J_t] = 0.098 \) (0.01)
Results: quadratic regulatory cost

- Quadratic regulatory cost: \( c(k, i) = c_i i + c_{ik} ki + c_{ii} i^2 \)
- Euler equation

\[
1 + c_i + c_{ik} k_t + 2 c_{ii} i_t + \eta_t = \beta \frac{\partial}{\partial k} E[\pi_{t+1} | J_t] + \\
+ \beta E[-c_{ik} i_{t+1} + 1 + c_i + c_{ik} k_{t+1} + 2 c_{ii} i_{t+1} | J_t]
\]

- Estimate from moment condition \( E[\eta_t | J_{t-1}] = 0 \)
### Results: quadratic regulatory cost

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate 1</th>
<th>Estimate 2</th>
<th>Estimate 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$ (fixed)</td>
<td>0.91</td>
<td>0.93</td>
<td>0.95</td>
</tr>
<tr>
<td>$\hat{c}_i$</td>
<td>0.005</td>
<td>0.038</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.19)</td>
<td>(0.28)</td>
</tr>
<tr>
<td>$\hat{c}_{ik} \times 10^{11}$</td>
<td>-7.4</td>
<td>-9.7</td>
<td>-13.8</td>
</tr>
<tr>
<td></td>
<td>(6.4)</td>
<td>(9.8)</td>
<td>(13.1)</td>
</tr>
<tr>
<td>$\hat{c}_{ii} \times 10^{11}$</td>
<td>-3.9</td>
<td>-5.1</td>
<td>-7.1</td>
</tr>
<tr>
<td></td>
<td>(3.3)</td>
<td>(5.0)</td>
<td>(6.7)</td>
</tr>
<tr>
<td>$\frac{\partial c}{\partial i}$</td>
<td>-0.007</td>
<td>0.30</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.16)</td>
<td>(0.25)</td>
</tr>
</tbody>
</table>
## Distribution across firms

<table>
<thead>
<tr>
<th>Percentile</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>95</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{\partial}{\partial k} E[\pi_{t+1}</td>
<td>J_t]$</td>
<td>0.079</td>
<td>0.088</td>
<td>0.095</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>$\frac{\partial c}{\partial i}$</td>
<td>0.072</td>
<td>0.15</td>
<td>0.28</td>
<td>0.36</td>
<td>0.38</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Correlation $\rho = 0.87$

$\beta = 0.93$
Estimated distribution of marginal product of capital and marginal regulatory investment cost
Investment incentives and price divergence

▶ Three obvious areas of price divergence
  1. Higher prices in the Northeast
  2. Lower prices at Opal hub in Indiana
  3. California energy crisis in late 2001

▶ Compare investment incentives of pipeline operating in these areas with other pipelines
Daily natural gas prices

![Graph showing daily natural gas prices from 1995 to 2015. Various pipeline names are plotted on the y-axis, including Agua Dulce, ANR SE, Carthage, Chicago Citygate, Columbia Gas, Columbia Gulf onshore, Enable East, Enable West, Henry Hub, Houston Ship Channel, Katy, NGPL S TX, NGPL TexOk, Northern Natural Demarc, OGT, Opal, Panhandle Eastern, Tennessee Line 500, Tennessee Line 800, Tennessee Zone 0 South, Texas Eastern E. LA, Texas Eastern M-3, Texas Eastern S. TX, Transco, Trunkline, and Waha. The x-axis represents the years from 1995 to 2015.]
Marginal regulatory cost by pipeline location

Pipeline investment

Empirical specification
Marginal product of capital by pipeline location

Pipeline investment

Empirical specification
Summary

- Estimated pipelines’ investment costs (including regulatory costs) from Euler Equations
  - Key assumption: information set of pipeline is observed or estimable
- Areas of pipeline congestion have:
  - Lower regulatory marginal investment cost
  - Lower expected marginal product of capital
- Aligning transmission prices with market prices may do more to relieve pipeline congestion than streamlining approval process
- Caveat: results do not say whether or not it is desirable to reduce congestion
Future research

- Estimate marginal value of pipeline capacity

- Incorporate details of network into model


Regulatory history

1978 Natural Gas Policy Act begins phase out of producer price regulation
1985 FERC Order 436 encourage third party access
1992 FERC Order 636 mandates full third party access
1996 FERC Order 889 requires transmission employees function independently from marketing employees
2000 FERC Order 637 requires open access online information on tariffs and daily auctions for released capacity
2003 FERC Order 2004 requires corporate separation of transmission and marketers
2006 Supreme Court overturns FERC Order 2004; requires “functional no-conduit rule” instead
2008 FERC revies Order 2004 to allow integrated planning, but still functional separation of transmission and marketing employees