# Estimating regulatory distortions of natural gas pipeline investment incentives

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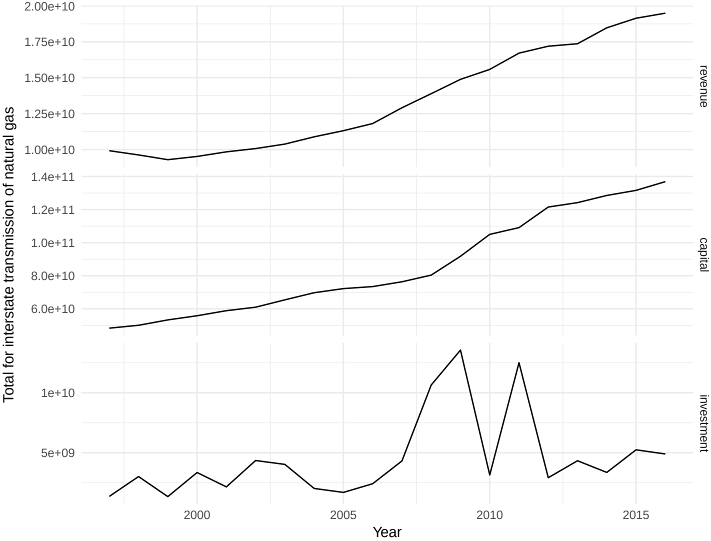
# Introduction

- 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



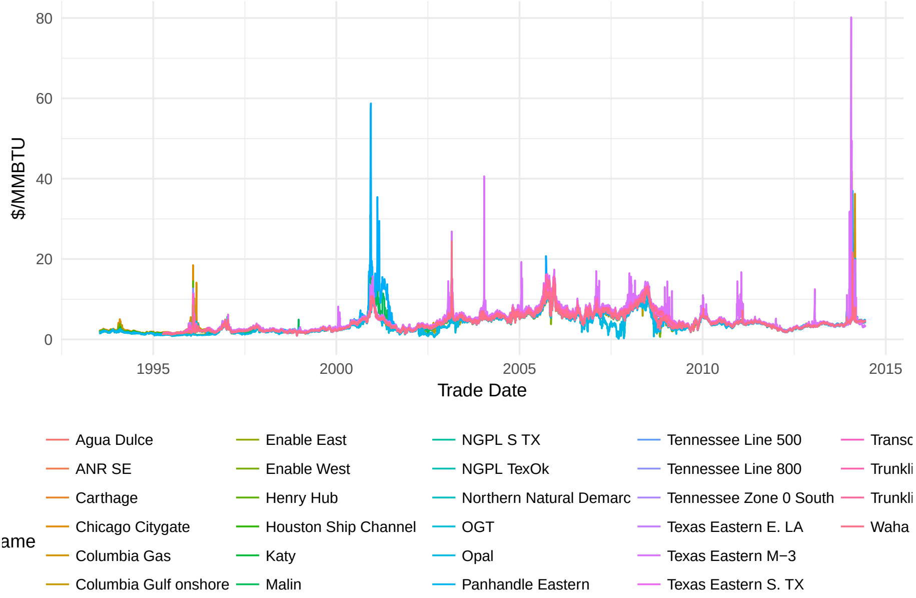
# Suggestive evidence of over-investment

- 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
  - von Hirschhausen (2008) : regulated rates of return average 11.6% for projects between 1996 and 2003
- 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
  - Cuddington and Wang (2006), Marmer, Shapiro, and MacAvoy (2007), Brown and Yücel (2008), Park, Mjelde, and Bessler (2008)
- 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 $\leqslant$ 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 assesments, 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:

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

where

- $k_{jt}$ = capital
- $i_{jt}$ = dollars of investment
- $\pi$ = variable profit function
- $x_{jt}$ = 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
- $\mathcal{I}_{jt}$ = information set of pipeline $j$ at time $t$

# Investment model

- Bellman equation:

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

- First order condition and envelope theorem gives Euler equation:

$$1 + \eta_{jt} + \frac{\partial c}{\partial i}(k_{jt}, i_{jt}) = \\ = \beta \mathrm{E}\left[ \begin{matrix} \frac{\partial \pi}{\partial k}(k_{jt+1}, x_{jt+1}) - \frac{\partial c}{\partial k}(k_{jt+1}, i_{jt+1}) + \\ 1 + \eta_{jt+1} + \frac{\partial c}{\partial i}(k_{jt+1}, i_{jt+1}) | \mathcal{I}_{jt} \end{matrix} \right]$$

# Identification of $c(k, i)$

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

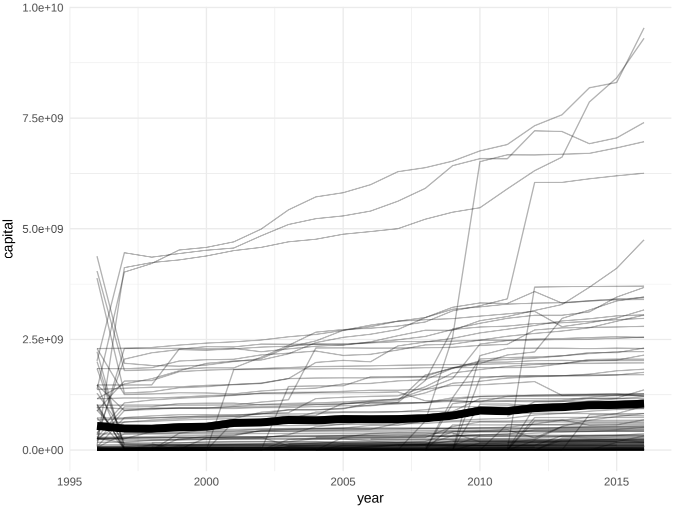
$$\mathrm{E}\left[\frac{\partial \pi}{\partial k}(k_{jt+1}, x_{jt+1}) | \mathcal{I}_{jt}\right] = \frac{\partial}{\partial k}\mathrm{E}\left[\pi_{jt+1} | \mathcal{I}_{jt}\right]$$

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

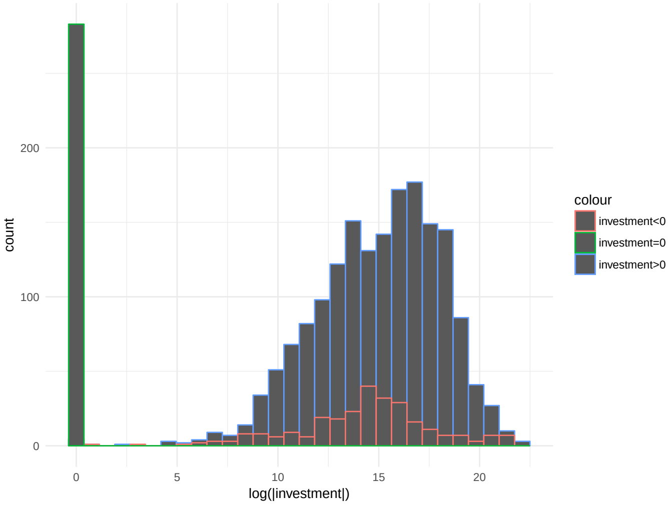
# Pipeline data

- FERC Form 2/2a annual data on pipeline companies
  - 1996-2016
  - 96-123 companies each year
  - detailed information about evenue, 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

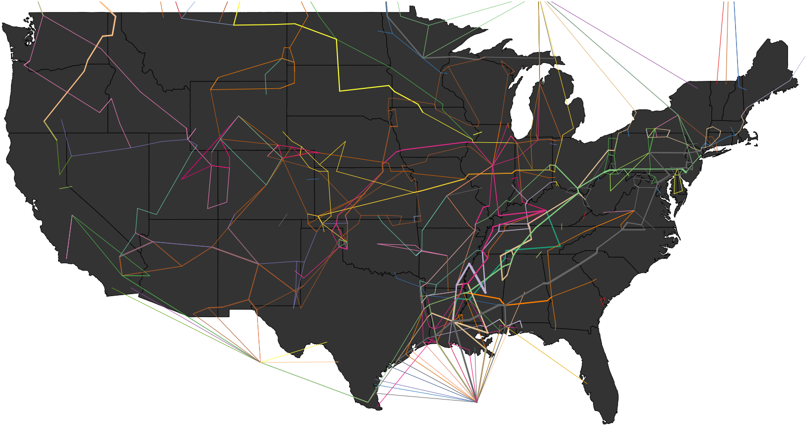
# Evolution of capital



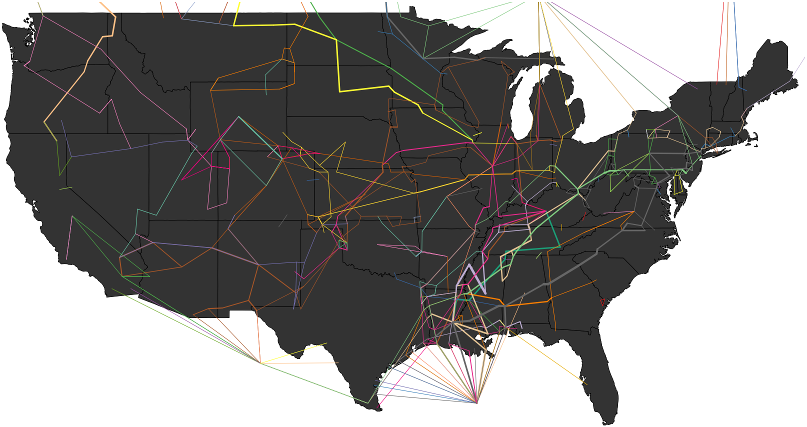
# Distribution of investment



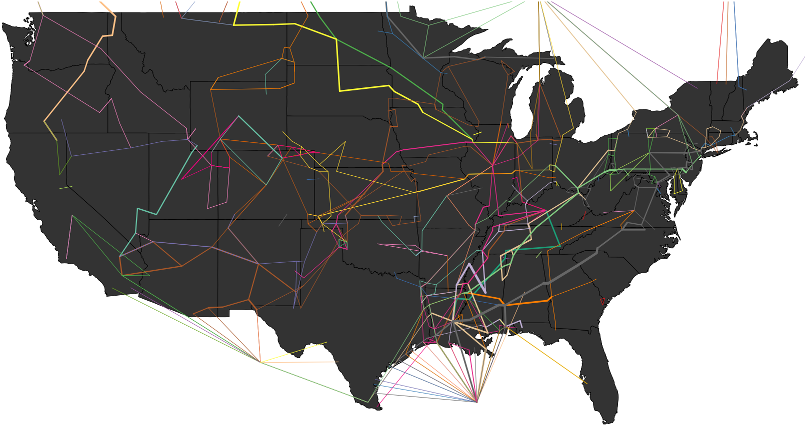
# Schematic pipeline network in 1996



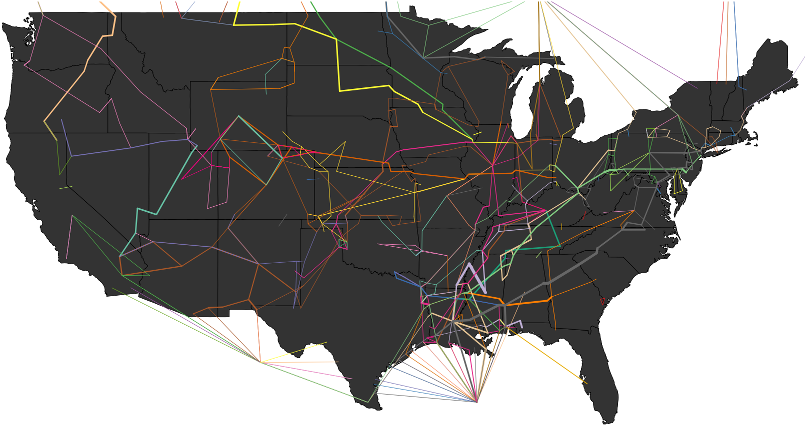
# Schematic pipeline network in 2001



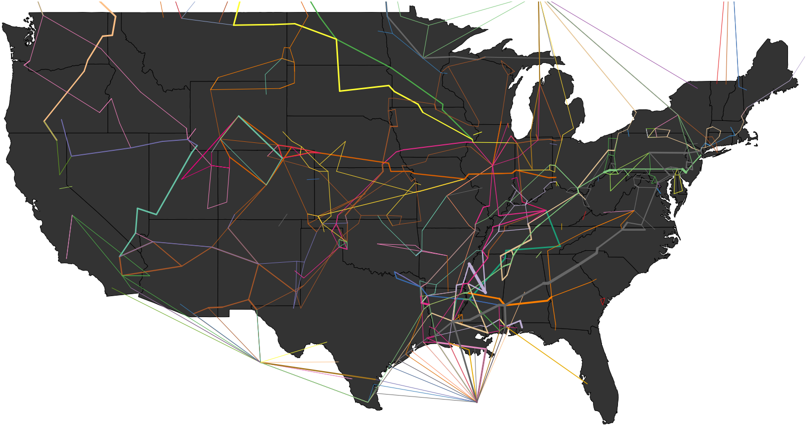
# Schematic pipeline network in 2006



# Schematic pipeline network in 2011



# Schematic pipeline network in 2016



# Empirical specification

- Information set , $\mathcal{I}_{jt} =$
  - capital, dekatherms of gas transmitted
  - total of pipelines that operate in the same states capital and transmission
  - year dummies
- $\frac{\partial}{\partial k}\mathrm{E}[\pi_{t+1}|\mathcal{I}_t]$ estimated by regression with all linear terms and second order terms involving capital
- Regulatory cost assumed to be either linear or quadratic
- Instruments $= \mathcal{I}_{jt-1}$

# Linear regulatory cost

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

$$(1 + c_i)(1 - \beta) + \eta_t = \beta \frac{\partial}{\partial k} \mathrm{E}[\pi_{t+1} | \mathcal{I}_t]$$

- Estimator

$$\widehat{c}_i = \frac{\beta}{1-\beta} \overline{\frac{\partial}{\partial k} \widehat{\mathrm{E}[\pi_{t+1} | \mathcal{I}_t]}} - 1$$

# Results : linear regulatory cost

| | | | | | | |
|---|---|---|---|---|---|---|
| $\widehat{\frac{\partial}{\partial k}\mathrm{E}[\pi_{t+1}\vert\mathcal{I}_t]}$ | | | 0.098 | | | |
| | | | (0.01) | | | |
| $\beta$ (fixed) | 0.90 | 0.91 | 0.92 | 0.93 | 0.94 | 0.95 |
| $\widehat{c}_i$ | -0.12 | -0.01 | 0.12 | 0.29 | 0.53 | 0.86 |
| | (0.11) | (0.12) | (0.14) | (0.16) | (0.19) | (0.24) |

# Results : quadratic regulatory cost

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

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

- Estimate from moment condition $\mathrm{E}[\eta_t | \mathcal{I}_{t-1}] = 0$

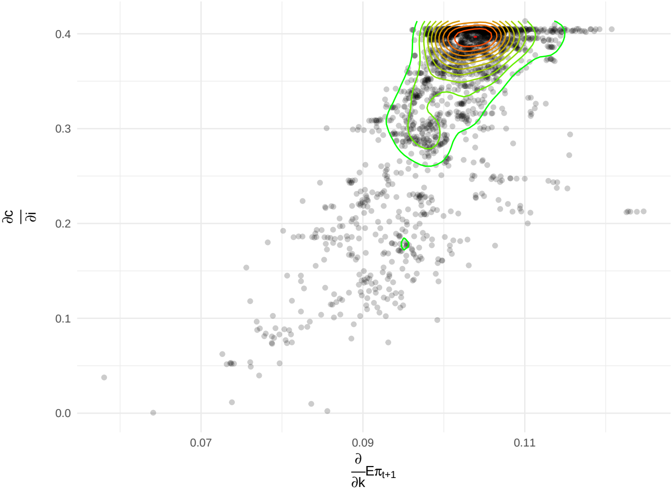
# Results : quadratic regulatory cost

| | | | |
|---|---|---|---|
| $\beta$ (fixed) | 0.91 | 0.93 | 0.95 |
| $\widehat{c}_i$ | 0.005 | 0.038 | 0.98 |
| | (0.15) | (0.19) | (0.28) |
| $\widehat{c}_{ik} \times 10^{11}$ | -7.4 | -9.7 | -13.8 |
| | (6.4) | (9.8) | (13.1) |
| $\widehat{c}_{ii} \times 10^{11}$ | -3.9 | -5.1 | -7.1 |
| | (3.3) | (5.0) | (6.7) |
| $\overline{\frac{\partial c}{\partial i}}$ | -0.007 | 0.30 | 0.86 |
| | (0.12) | (0.16) | (0.25) |

# Distribution across firms

| | Percentile | | | | | |
|---|---|---|---|---|---|---|
| | 5 | 10 | 25 | 50 | 75 | 95 |
| $\frac{\partial}{\partial k}\mathrm{E}[\pi_{t+1} \vert \mathcal{I}_t]$ | 0.079 | 0.088 | 0.095 | 0.1 | 0.1 | 0.11 |
| $\frac{\partial c}{\partial i}$ | 0.072 | 0.15 | 0.28 | 0.36 | 0.38 | 0.38 |
| Correlation | 0.87 | | | | | |
| $\beta = 0.93$ | | | | | | |

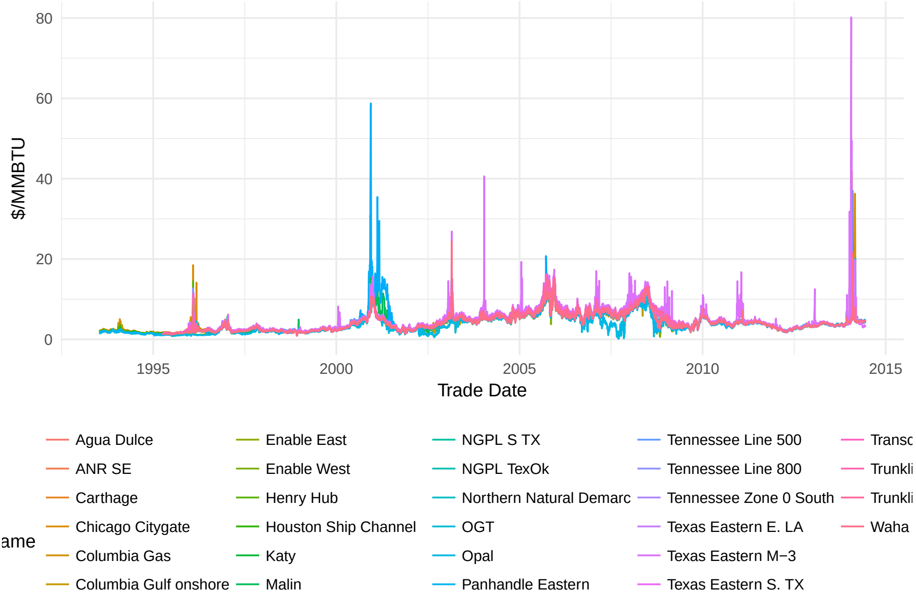
# Estimated distribution of marginal product of capital and marginal regulatory investment cost



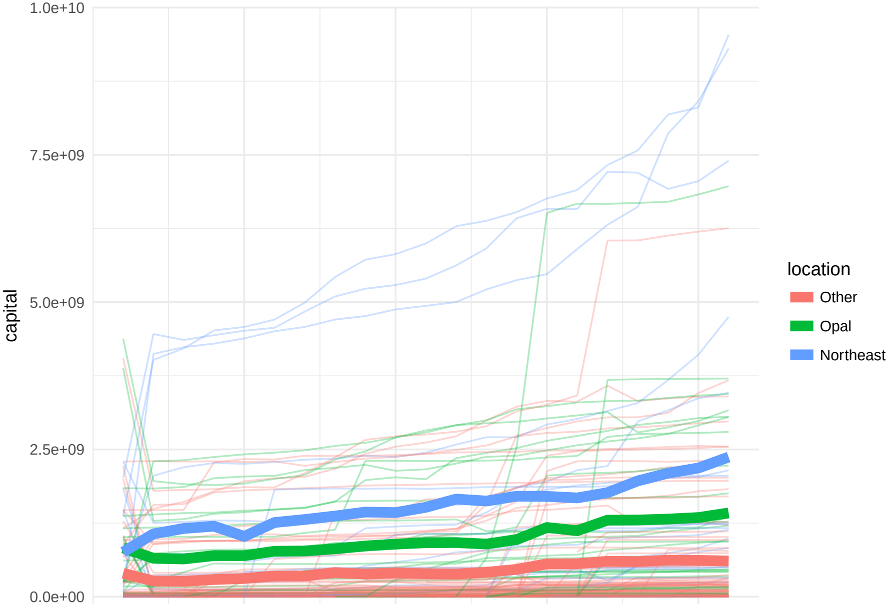
# Investment incentives and price divergence

- 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

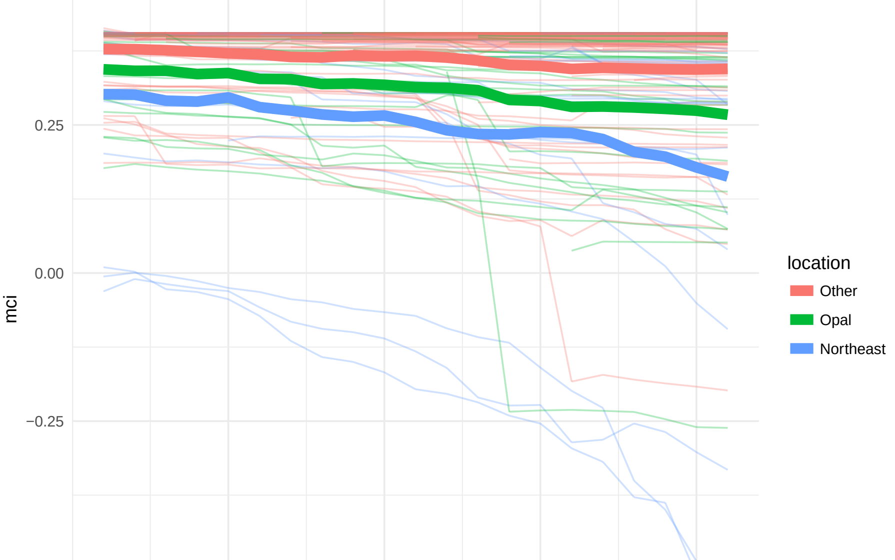
# Daily natural gas prices



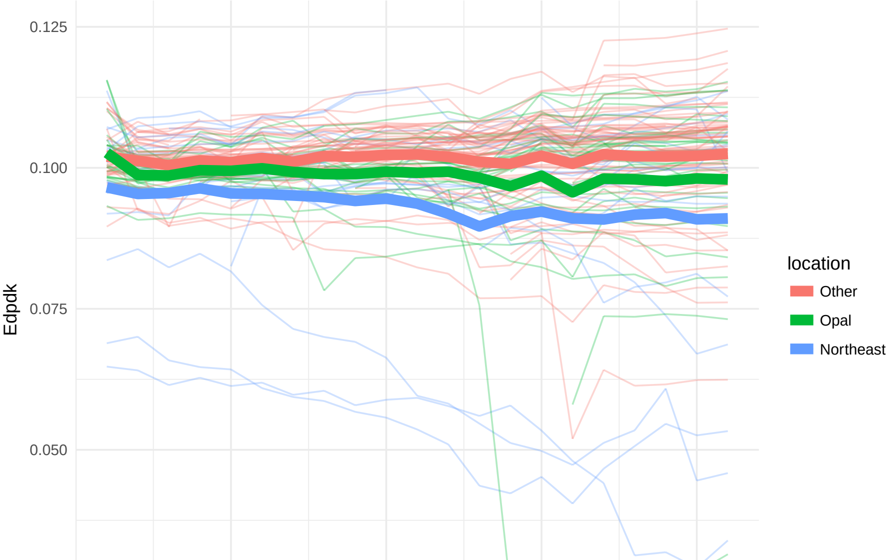
# Capital by pipeline location



# Marginal regulatory cost by pipeline location



# Marginal product of capital by pipeline location



# 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
  - Model of Cremer and Laffont (2002), Cremer, Gasmi, and Laffont (2003) : marginal value of capacity = price differential - marginal cost of transport
- Incorporate details of network into model

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# 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