Accuracy of Policymaker Predictions of Compliance Costs
The Role of Banking

Sylwia Bialek†∥, Jeffrey Shrader‡

†Institute for Policy Integrity, New York University
∥ Goethe University Frankfurt
‡ School of International and Public Affairs, Columbia University

September 2019
Object of interest - policies with **storable permits**

- cap-and-trade programs (RGGI, EU ETS, Acid Rain Program)
- U.S.: most Renewable Portfolio Standards, Australian Renewable Energy Targets
- Phasedown of Lead in Gasoline
- Corporate Average Fuel Economy standards
Object of interest - policies with **storable permits**

- cap-and-trade programs (RGGI, EU ETS, Acid Rain Program)
- U.S.: most Renewable Portfolio Standards, Australian Renewable Energy Targets
- Phasedown of Lead in Gasoline
- Corporate Average Fuel Economy standards

Why study the banking behavior?

- interpretation of the banking behavior in such programs
Object of interest - policies with **storable permits**
- cap-and-trade programs (RGGI, EU ETS, Acid Rain Program)
- U.S.: most Renewable Portfolio Standards, Australian Renewable Energy Targets
- Phasedown of Lead in Gasoline
- Corporate Average Fuel Economy standards

Why study the banking behavior?
- interpretation of the banking behavior in such programs
- “good” and “bad” banking
“Good” and “bad” banking

Banking reduces aggregate economic costs and decreases fluctuations in allowance prices.
“Good” and “bad” banking

Banking reduces aggregate economic costs and decreases fluctuations in allowance prices.

“Bad” side of banking- in case of too lenient standards.

California’s cap-and-trade system may be too weak to do its job

Banking was originally a feature of the cap-and-trade program, meant to smooth year-to-year fluctuations in prices and give investors confidence. But it has become a bug.

Object of interest - policies with **storable permits**

- cap-and-trade programs (RGGI, EU ETS, **Acid Rain Program**)
- U.S.: most Renewable Portfolio Standards, Australian Renewable Energy Targets
- Phasedown of Lead in Gasoline
- **Corporate Average Fuel Economy** standards

Why study the banking behavior?

- interpretation of the banking behavior in such programs
- ”good” and ”bad” banking
- evaluating policymakers’ decisions fairly

**Related literature**
How to judge regulator accuracy?

Assume a new regulation is imposed in 2020. It requires all wooden utility poles to be replaced with steel ones by 2022. The CBA run by the regulator estimates the costs to be $100 million. Consider alternative retrospective reviews done in 2025 that find costs were either
How to judge regulator accuracy?

Assume a new regulation is imposed in 2020. It requires all wooden utility poles to be replaced with steel ones by 2022. The CBA run by the regulator estimates the costs to be $100 million. Consider alternative retrospective reviews done in 2025 that find costs were either

- $110 million because the regulator slightly underestimated the price response of steel to the increased demand
- $150 million because a new 5-year program released in 2021 in China drew heavily on steel-based products, increasing the price for steel
- $60 million because a hurricane in January 2021 destroyed most of the existing wooden poles so they had to be exchanged anyway
How to judge regulator accuracy?

Assume a new regulation is imposed in 2020. It requires all wooden utility poles to be replaced with steel ones by 2022. The CBA run by the regulator estimates the costs to be $100 million. Consider alternative retrospective reviews done in 2025 that find costs were either

- $110 million because the regulator slightly underestimated the price response of steel to the increased demand
- $150 million because a new 5-year program released in 2021 in China drew heavily on steel-based products, increasing the price for steel
- $60 million because a hurricane in January 2021 destroyed most of the existing wooden poles so they had to be exchanged anyway

How should unpredictable events orthogonal to the policy-making be considered when evaluating the policy?
With changing regulation stringency and banking, firms try to "smooth" their compliance costs over time. The amount of banking is informative about the compliance costs.
With changing regulation stringency and banking, firms try to "smooth" their compliance costs over time. The amount of banking is informative about the compliance costs.

**Figure:** Compliance choice with flat marginal abatement cost curve
With changing regulation stringency and banking, firms try to "smooth" their compliance costs over time. The amount of banking is informative about the compliance costs.
With changing regulation stringency and banking, firms try to "smooth" their compliance costs over time. The amount of banking is informative about the compliance costs.

\[
c'(A_t) = \delta c'(A_{t+1})
\]

**Figure:** Compliance choice with steep marginal abatement cost curve
Intuition for the method & early observations

▶ Basic idea is pure Hotelling
  ▶ Firms bank when they expect future compliance costs to be high
  ▶ The higher the future compliance cost, the (weakly) more banking done
  ▶ Firms un-bank when the future arrives
Intuition for the method & early observations

- Basic idea is pure Hotelling
  - Firms bank when they expect future compliance costs to be high
  - The higher the future compliance cost, the (weakly) more banking done
  - Firms un-bank when the future arrives

- With increasing stringency and possibility of credits banking the observed compliance costs (e.g. reflected by credit prices) are higher than the costs associated with the stringency level set for the given period.

- With perfect banking possibilities, the upper limit on the total cost of compliance that firms expected at the beginning of the program, can be computed based on the observed first-period prices.
Model & its application

We build a basic compliance choice model that connects banking to abatement costs curves, allowing for structural estimation.

We apply the method to SO\(_2\) permits in the Acid Rain Program (ARP) and Corporate Average Fuel Economy (CAFE) compliance credits.
Acid Rain Program

- Pro 1: Very clear changes in stringency and banking behavior
- Pro 2: Program parameters were fixed in advance and unchanged for roughly 9 years
- Pro 3: Simple institutional setup
- Con: Trading makes inference on per-period abatement cost expectations much harder
Acid Rain Program

- Pro 1: Very clear changes in stringency and banking behavior
- Pro 2: Program parameters were fixed in advance and unchanged for roughly 9 years
- Pro 3: Simple institutional setup
- Con: Trading makes inference on per-period abatement cost expectations much harder

CAFE standards

- Pro: No trading (pre-2012) allows for richer, firm-level estimation
- Con 1: Lack of permit/allowance prices and consumer valuation of fuel economy both mean we need to get more structural
- Con 2: Consumers value fuel economy depending on the gasoline prices - need to get more structural
Stringency, Banking, and Permit Price

![Graph showing allowances and price over time.]

- Stringency (counterfactual minus cap)
- Banked allowances
- Secondary market price
- Auction settle price

Program design
Estimation of SO$_2$ marginal abatement costs

Rational expectations estimation derived from Euler equation:

$$\Delta \ln(p_t) = \gamma_0 + \gamma_1 \ln(\varepsilon_t - Y_t + \Delta S_{t+1}) + \gamma_2 \ln(\varepsilon_{t-1} - Y_{t-1} + \Delta S_t) + \nu_t$$

We can identify marginal abatement costs from this equation. Data:

- $p$ is permit price (from EPA auctions or secondary market)
- $\varepsilon$ is counterfactual emissions (estimated using Schmalensee *et al.* 1998 heat input method)
- $Y$ is number of permits issued (from EPA)
- $\Delta S$ is the change in banked permits (from EPA)

Use instrumental variables with OLS to get the estimates.
SO$_2$ program results

- During Phase I market banked 2 mln allowances per year rising effective stringency by 200% - banking raised prices by ca. $60$-$70$
SO$_2$ program -results

- During Phase I market banked 2 mln allowances per year rising *effective stringency* by 200% - banking raised prices by ca. $60-$70

- Given permit price of $120 - the marginal costs of abatement for *regulatory stringency* during Phase I was very low- $50 per ton of abatement
SO$_2$ program -results

- During Phase I market banked 2 mln allowances per year rising effective stringency by 200% - banking raised prices by ca. $60-$70

- Given permit price of $120 - the marginal costs of abatement for regulatory stringency during Phase I was very low- $50 per ton of abatement

- During Phase II, market used 1 million banked allowances per year, decreasing permit price from $210 absent banking to $180.
SO$_2$ program - results

- During Phase I market banked 2 mln allowances per year rising *effective stringency* by 200% - banking raised prices by ca. $60-$70
- Given permit price of $120 - the marginal costs of abatement for *regulatory stringency* during Phase I was very low- $50 per ton of abatement
- During Phase II, market used 1 million banked allowances per year, decreasing permit price from $210 absent banking to $180.
- EPA projections:
  - projections before the start of the program $400-$1000
  - in the 2000’s EPA used permit price as compliance cost
Fuel economy standards for different types of vehicles and development of oil prices
Fuel economy performance and standards for individual manufacturers: Light trucks
CAFE credit banking

Light Trucks

Passenger Cars
Identifying the cost curve for CAFE compliance

Structural estimation based on the model of auto manufacturers choice of fuel economy and prices

$$\max_{P_t, mpg_t} \sum_{i=t}^{\infty} \delta^{i-t} [P_i - c(mpg_i)] \cdot Q(P_i, mpg_i, p_{oil}^i)]$$

$$- \lambda \left( \sum_{i=t}^{T} mpg_i Q_i - \sum_{i=t}^{T} MPG_i Q_i + B_t \right),$$

We estimate demand and supply parameters using rational-expectations GMM. The fuel cost sensitivity of vehicle demand is estimated outside the main model.
CAFÉ Results

- the marginal cost of fuel efficiency at levels prescribed by CAFE for light truck was very low and only around in 2010 grew to around $60 per mpg (for 24 mpg requirement)
- the marginal cost of fuel efficiency at levels prescribed by CAFE for passenger cars in 1985 (27.5 mpg) were already high
  - $159.5-$290 for imported cars
  - $341.75-$900 for domestic cars

Fleet-wide results

Results for individual manufacturers
CAFE Results cd

- The high fuel economy costs required by standards for 1985, combined with very low initial CAFE requirements and the associated low marginal fuel economy costs gave strong incentive for CAFE-driven overcompliance
- Initial overcompliance in light trucks seems to be driven by demand for fuel economy, not cost smoothing
Thank you for listening.
Related literature

- Modeling firms’ banking decisions (Rubin & Kling 1993; Kling & Rubin 1997; Schennach 2000)


- Estimation involving beliefs (Meng 2017; Chen 2018)
Acid Rain Program implemented cap and trade of SO$_2$ permits starting in 1995

- Phase I (1995-1999) placed loose cap on most polluting electricity generating units (EGUs)
- Phase II in 2000 encompassed additional small units and tightened cap
- Unlimited banking allowed between years (and phases)
- March 2005 final rule issued for Clean Air Interstate Rule (CAIR) tightened the cap further
- CAIR was not expected during the first 8 or 9 years of the Acid Rain Program
- Substantial legal uncertainty around CAIR: we limit our analysis to pre-2005
- 1995 through 2004 period is an ideal test-bed for the basic theory
Estimation of SO$_2$ marginal abatement costs

Recall Euler equation

$$
E_t \left( \frac{p_{t+1}}{p_t} \right) = E_t \left( \frac{\delta c'(\varepsilon+1 - Y_t + \Delta S_{t+2})}{c'(\varepsilon_t - Y_t + \Delta S_{t+1})} \right)
$$

We can identify market-wide marginal abatement costs from this equation. Our primary results will take logs and estimate

$$
\Delta \ln(p_t) = \gamma_0 + \gamma_1 \ln(\varepsilon_t - Y_t + \Delta S_{t+1}) + \gamma_2 \ln(\varepsilon_{t-1} - Y_{t-1} + \Delta S_t) + \nu_t
$$

Structural assumption is that $\gamma_1 = -\gamma_2$.

We instrument for $\varepsilon - Y + \Delta S$ using announced permit issuance levels. We also use firm’s level data and use belief-shifters as instruments.
Corporate Average Fuel Economy standards

- Fuel economy regulations for passenger cars were first set in 1975 and stipulated for years 1978-1985 and forwards with possibility of overriding updates
- Fuel economy regulations for passenger cars were first set in 1977 and stipulated for years 1979, regular updates for next years
- Manufacturers allowed to carry overcompliance credits backward or forward (borrowing and banking)
- No trading (before 2012) so no prices⇒ more structure on model
- But the standards were set per fleet, so no trading ⇒ inference on firm-level compliance costs possible
- Fleet definitions have changed over the years
Fuel economy performance and standards for individual manufacturers: Passenger cars
Figure: Difference between CAFE standards and actual fuel efficiency

Notes: The points show the difference between the average fuel efficiency achieved and the fuel efficiency prescribed by the standards for the individual fleets. Credits accumulated in previous years are not considered. The line shows the average across fleets and brands.
## Initial CAFE evidence: Banking responds to stringency

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stringency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t+1$</td>
<td>0.613***</td>
<td>0.426***</td>
<td>0.653***</td>
<td>0.426***</td>
</tr>
<tr>
<td>$t+2$</td>
<td>0.493**</td>
<td>0.236*</td>
<td>0.387*</td>
<td>0.236*</td>
</tr>
<tr>
<td>$t+3$</td>
<td>0.340***</td>
<td>0.229</td>
<td>0.348***</td>
<td>0.229</td>
</tr>
<tr>
<td>$t-1$</td>
<td>0.479***</td>
<td>0.364***</td>
<td>0.261***</td>
<td>0.364***</td>
</tr>
<tr>
<td>$t-2$</td>
<td>0.209**</td>
<td>0.213***</td>
<td>0.209*</td>
<td>0.209*</td>
</tr>
<tr>
<td>$t-3$</td>
<td>0.169</td>
<td>0.122*</td>
<td>0.169</td>
<td>0.169</td>
</tr>
<tr>
<td><strong>Oil price</strong></td>
<td>0.0172**</td>
<td>0.0264***</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year FE</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Fleet FE</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Brand FE</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Cluster level</strong></td>
<td>brand-fleet</td>
<td>brand-fleet</td>
<td>brand-fleet</td>
<td>brand</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>869</td>
<td>869</td>
<td>869</td>
<td>869</td>
</tr>
<tr>
<td><strong>$R^2$</strong></td>
<td>0.566</td>
<td>0.642</td>
<td>0.575</td>
<td>0.437</td>
</tr>
</tbody>
</table>

Relative stringency is the difference in required mpg levels between the period in which the overcompliance in observed ($t$) and the required mpg in the respective future or past period.
CAFE model details

Important model features

- both banking and borrowing
- no aggregate cap
- consumers value the compliance (fuel economy) directly

The first order conditions are

\[(1) \quad Q_t + [P_t - c(mpg_t)] \cdot Q'_{t,P} = \lambda Q'_{t,P}(mpg_t - MPG_t)\]
\[(2) \quad [P_t - c(mpg_t)] \cdot Q'_{t,mpg} - c'_t Q_t = \lambda (Q'_{t,mpg}(mpg_t - MPG_t) + Q_t)\]
GMM Equations for CAFE

The first order conditions yield two estimating equations:

An intertemporal equation (the CAFE equivalent of the ARP estimating equation)

\[
E \left[ z \left( \frac{[P_t - F - \beta_1 mpg_t - \beta_2 mpg_t^2]}{\gamma_2 B_t \cdot p_{oil}^2 / mpg_t^2 + Q_t} \cdot \gamma_2 p_{oil}^2 / mpg_t^2 - (\beta_1 + \beta_2 mpg_t) Q_t \right) - \delta \cdot \left( \frac{[P_{t+1} - F - \beta_1 mpg_{t+1} - \beta_2 mpg_{t+1}^2]}{\gamma_2 B_{t+1} \cdot p_{oil}^2 / mpg_{t+1}^2 + Q_{t+1}} \cdot \gamma_2 p_{oil}^2 / mpg_{t+1}^2 - (\beta_1 + \beta_2 mpg_{t+1}) Q_{t+1} \right) \right] = 0
\]

An intra-temporal equation describing the tradeoff between demand increases due to fuel economy increases versus the cost of raise fuel economy

\[
E \left[ z \left( \frac{P_t - Q_t / \gamma_1 - F - \beta_1 mpg_t - \beta_2 mpg_t^2}{B_t} \cdot \frac{B_t - Q_t \cdot mpg_t^2 / 2 \gamma_2 p_{oil}^2}{B_t - Q_t \cdot mpg_t^2 / 2 \gamma_2 p_{oil}^2} \right) \right] = 0
\]
Estimate fuel cost sensitivity using vehicle demand for individual model \( i \) in year \( t \), month \( m \) of the form:

\[
Q_{tmi} = \alpha + \alpha_m - \gamma_1 P_{it} - \gamma_2 \frac{p_{oil}^{tm}}{mpg_{ti}} - \gamma_3 unempl_{tm} - \gamma_4 GDP_{tm} + \nu_{it} + \epsilon_{tmi}
\]

We use data 1987-1997 data on prices and monthly registrations for a few passenger car models combined with data on gasoline prices and unemployment.

The estimated value suggests that if Nissan were to increase the fuel efficiency of its 300ZX model in 1990 from 18 to 19 mpg, the monthly sales would have increased by 61 units, compared to the usual sales of 2000 units.
<table>
<thead>
<tr>
<th></th>
<th>(A)</th>
<th>(B)</th>
<th>(C)</th>
<th>(D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>-16341**</td>
<td>-16810.56**</td>
<td>-12062.09*</td>
<td>-12717.06*</td>
</tr>
<tr>
<td></td>
<td>(7186)</td>
<td>(7052.5)</td>
<td>(7043)</td>
<td></td>
</tr>
<tr>
<td>lag unempl</td>
<td>-394.01</td>
<td>-438.07*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(251)</td>
<td>(246.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lag GDP</td>
<td>-.76</td>
<td>-1.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.69)</td>
<td>(1.66)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unemployment</td>
<td></td>
<td></td>
<td>-572.59**</td>
<td>-543.3**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(239.6)</td>
<td>(236.05)</td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td></td>
<td>-3.74*</td>
<td>-3.69*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>N</td>
<td>3068</td>
<td>3004</td>
<td>3132</td>
<td>3060</td>
</tr>
<tr>
<td>month FE</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>model-year FE</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>No jumps in mpg</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0.917</td>
<td>0.919</td>
<td>.917</td>
<td>0.918</td>
</tr>
</tbody>
</table>
**Table:** Estimates of model parameters for individual car manufacturers

<table>
<thead>
<tr>
<th></th>
<th>(FORD)</th>
<th>(SUZ)</th>
<th>(NISS)</th>
<th>(KIA)</th>
<th>(MITS)</th>
<th>(TOY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>13404</td>
<td>36709.7***</td>
<td>27863***</td>
<td>106520.7***</td>
<td>77907</td>
<td>17900.5</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>-697.8</td>
<td>-1610.2***</td>
<td>-206.9</td>
<td>-7866***</td>
<td>-5286</td>
<td>454.5</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>43.7*</td>
<td>42.6***</td>
<td>10</td>
<td>183.6***</td>
<td>149.6</td>
<td>10.5</td>
</tr>
<tr>
<td>$\gamma_1$</td>
<td>158.3***</td>
<td>62.63</td>
<td>-2010000</td>
<td>50.543***</td>
<td>-577680</td>
<td>-5280000</td>
</tr>
</tbody>
</table>

| N     | 17     | 13        | 14        | 13        | 13         | 14        |
| Fl    | D      | LT        | LT        | LT        | LT         | LT        |

**Notes:** $\gamma_2$ (fuel economy sensitivity) was set to 161376 based on fuel economy valuation regression. The specifications use oil prices, unemployment rate, and GDP values known at the time $t - 18$ months as well as relative past CAFE stringency for instruments. Fleet prices used for estimation are based on the average price of all models of vans, pickups and SUVs offered by the manufacturer in a given model year. The low observation numbers follow from changes in fleet definition.
**Table:** Estimates of model parameters for fleet averages

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(1)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>155922.5**</td>
<td>16482.01***</td>
<td>79425.7***</td>
<td>30614.46***</td>
<td>32132.2***</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>-12430.1***</td>
<td>-218.7</td>
<td>-4308.6**</td>
<td>-1089.4</td>
<td>-1063.71***</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>277.3***</td>
<td>10.19**</td>
<td>91.3**</td>
<td>35.3</td>
<td>22.24***</td>
</tr>
<tr>
<td>$\gamma_1$</td>
<td>-5560000</td>
<td>14433.16***</td>
<td>17826</td>
<td>1350000</td>
<td>-123000</td>
</tr>
<tr>
<td>N</td>
<td>77</td>
<td>14</td>
<td>138</td>
<td>365</td>
<td>55</td>
</tr>
<tr>
<td>FL</td>
<td>D PC</td>
<td>D PC</td>
<td>LT</td>
<td>I PC</td>
<td>I PC</td>
</tr>
</tbody>
</table>

**Notes:** “LT” - some of the domestically produced light trucks for years before 1997 and all light trucks from 1997 on. $\gamma_2$ was set to 161376 based on fuel economy valuation regression. The specifications use oil prices, unemployment rate, and GDP values known at the time $t - 18$ months as well as relative past CAFE stringency for instruments. Fleet prices are based on the CPI index data for new trucks and new cars in U.S. cities. For LT index is available from 1983.