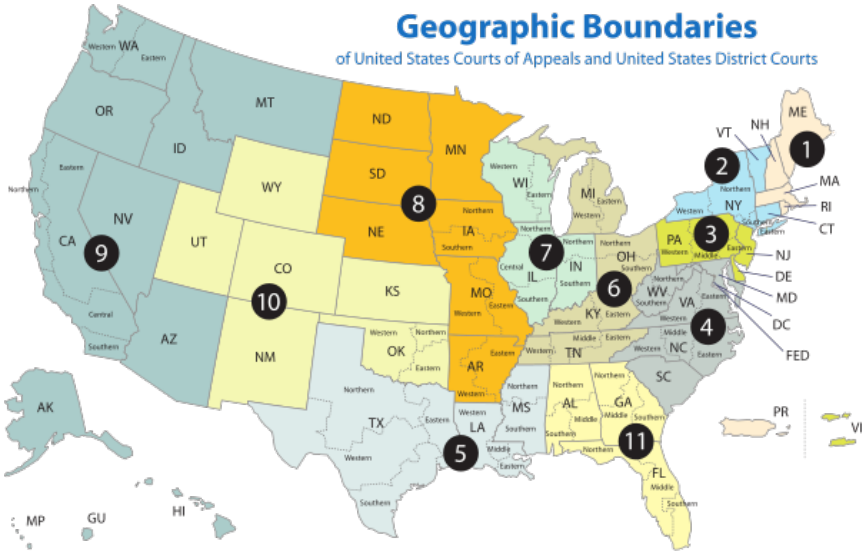
Deep IV in Law
Towards Automated Impact Analysis of Judicial Precedents

Daniel L. Chen

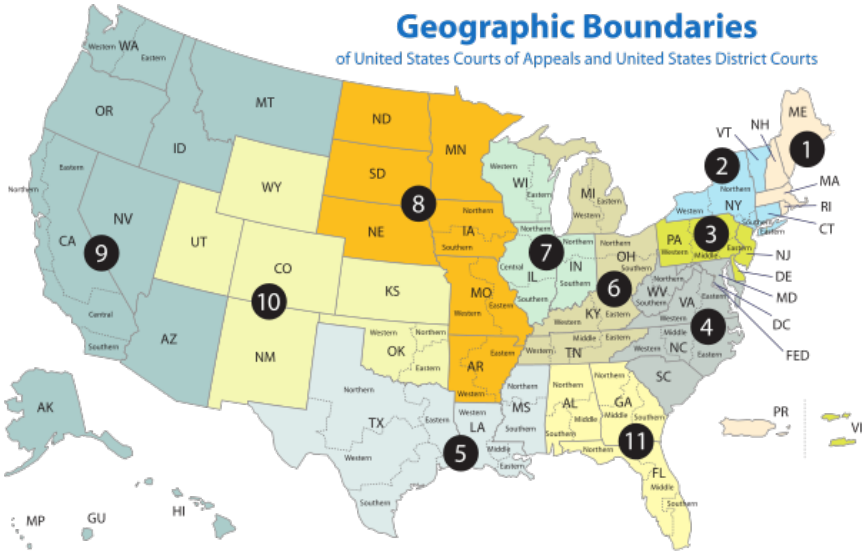
December 2019

US Federal Courts as Natural Laboratory



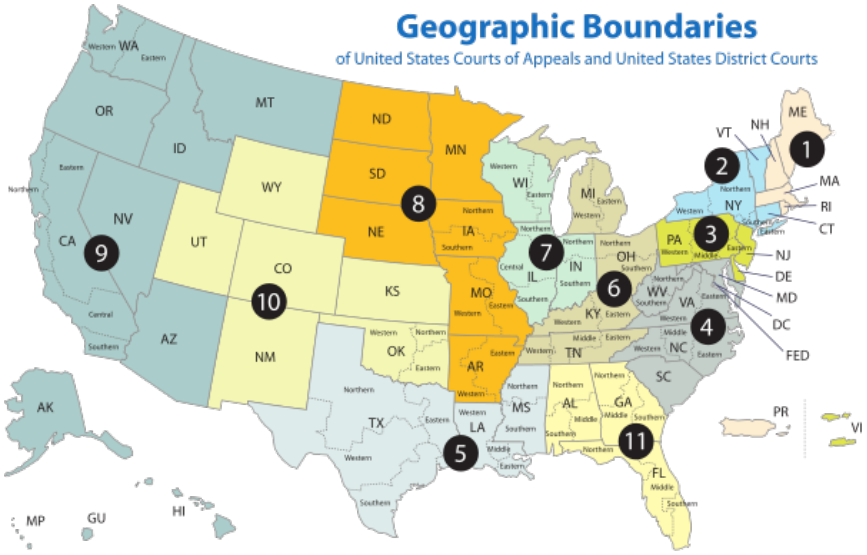
- **Random** assignment of judges
  - Judge characteristics **predict** decisions
- Binding precedent **within** circuit
  - 98% of decisions are final

US Federal Courts as Natural Laboratory



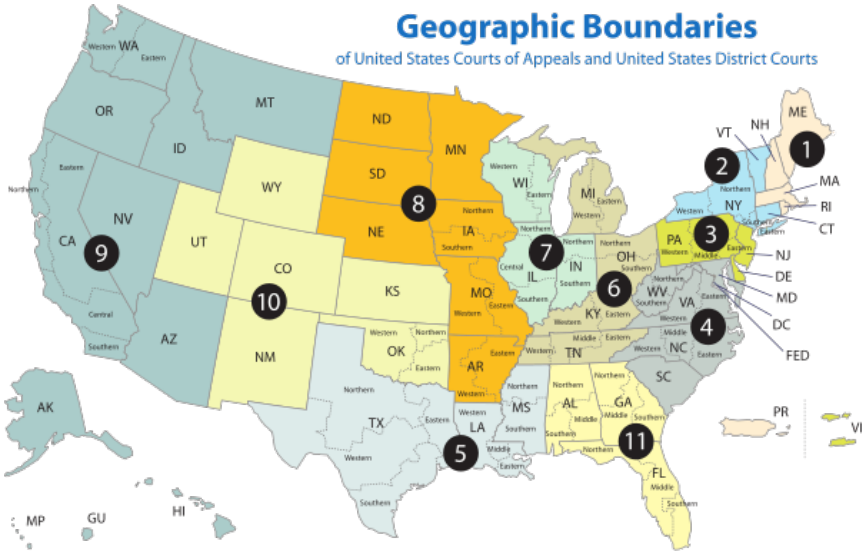
- **Random** assignment of judges
  - Judge characteristics **predict** decisions
- Binding precedent **within** circuit
  - 98% of decisions are final

US Federal Courts as Natural Laboratory



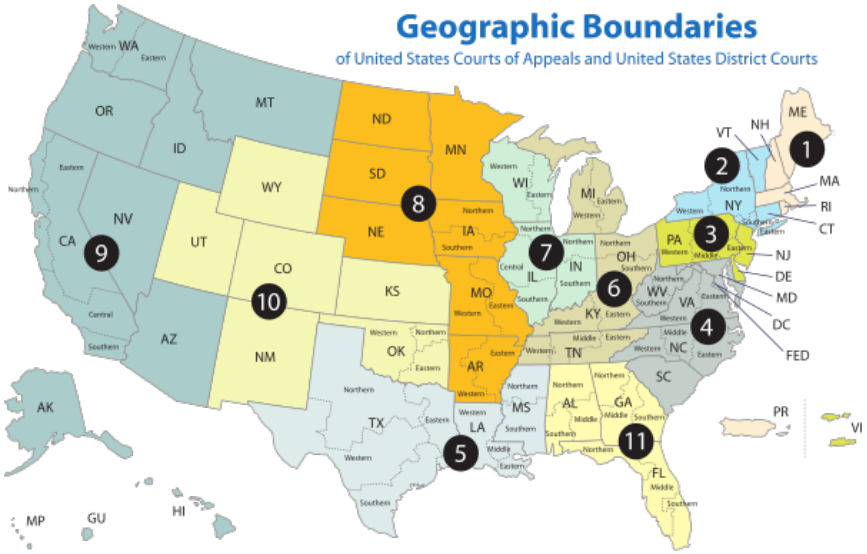
- **Random** assignment of judges
  - Judge characteristics **predict** decisions
- Binding precedent **within** circuit
  - 98% of decisions are final

US Federal Courts as Natural Laboratory



- **Random** assignment of judges
  - Judge characteristics **predict** decisions
- Binding precedent **within** circuit
  - 98% of decisions are final

US Federal Courts as Natural Laboratory



- **Random** assignment of judges
  - Judge characteristics **predict** decisions
- Binding precedent **within** circuit
  - 98% of decisions are final

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)
- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.
- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- Waive **need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to $<$ 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to $<$ 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

High-stakes common-law space

Introduce theories:

- **Contract duty posits a general obligation to keep promises** vs.
- a party should be allowed to breach a contract and pay damages, if it's more economically efficient than performing (i.e., efficient breach theory) (Posner 7th Cir. 1985)

- **Tort law: duty of care** assigned to minimize costs ("least cost avoider" theory)

Shift in standards or thresholds:

- Shift from **reasonable person** standard to **reasonable woman** standard for what constitutes sexual harassment.

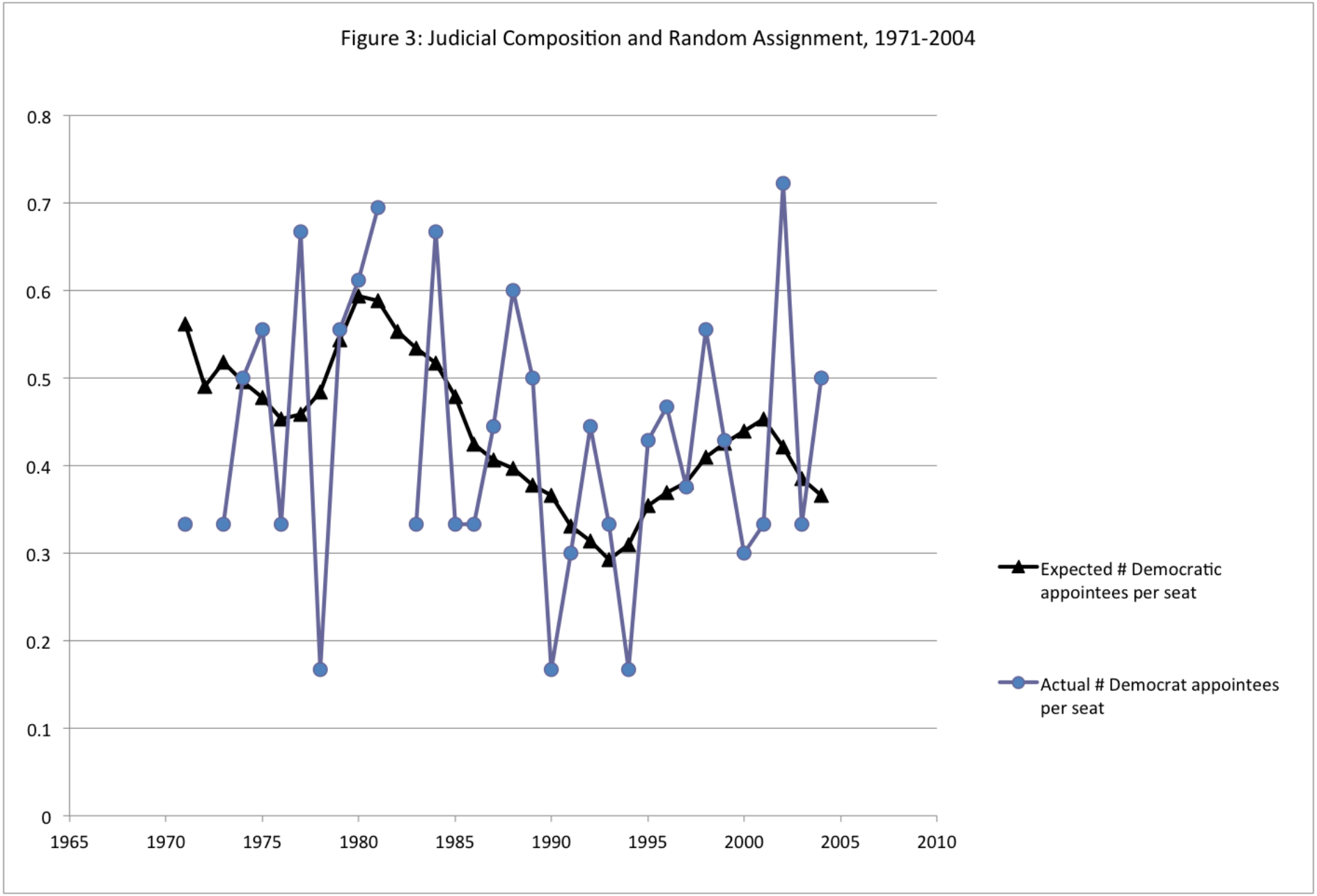
- **Waive need to prove emotional harm** in court by plaintiff (to a jury).

Rule on states' laws:

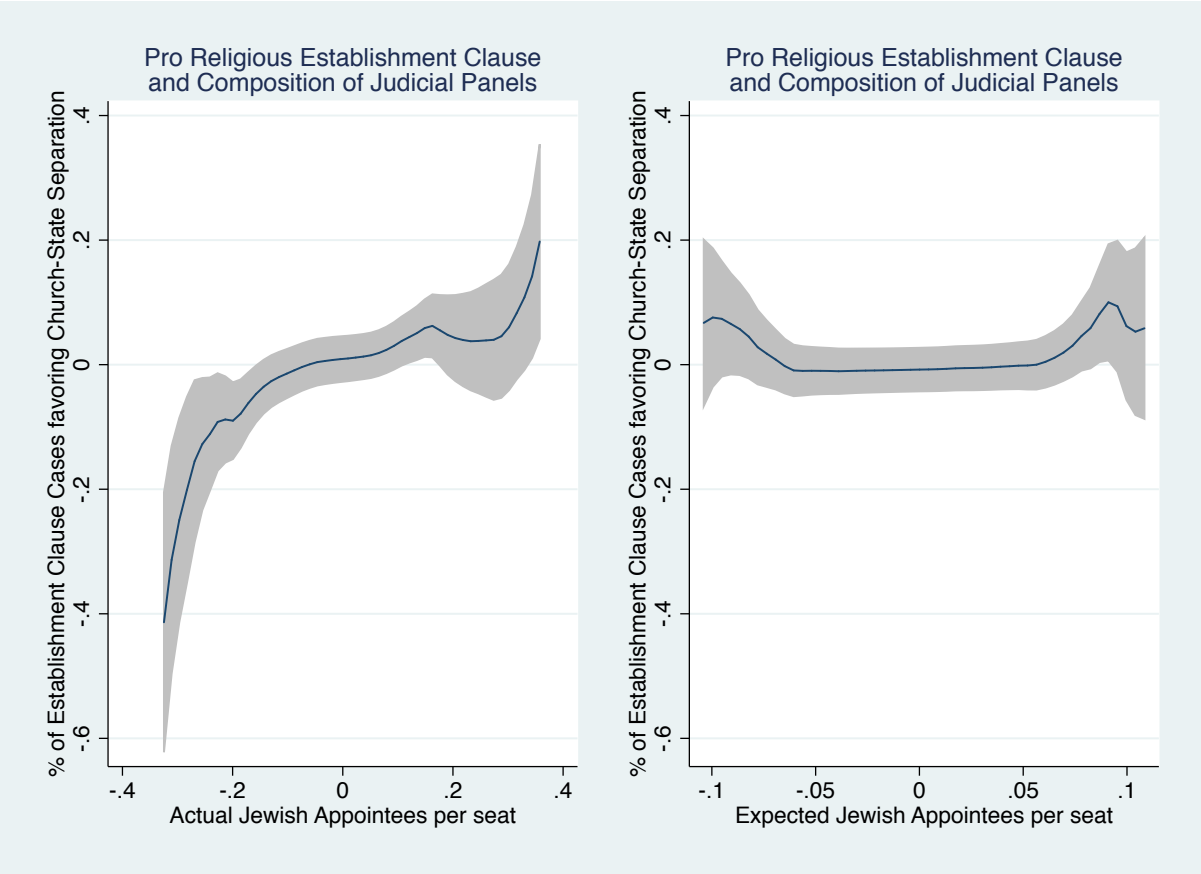
- 5th Circuit **allowed** Texas law *requiring abortion clinics to meet building standards of ambulatory surgery centers*. (would reduce to < 10 clinics)

What are causal effects of rulings like these?

Graphical Intuition of "coin flip"



Biographies Predict Votes *What Matters, Chen, Cui, Shang, Zheng, NeurIPS-MLaw 2016*

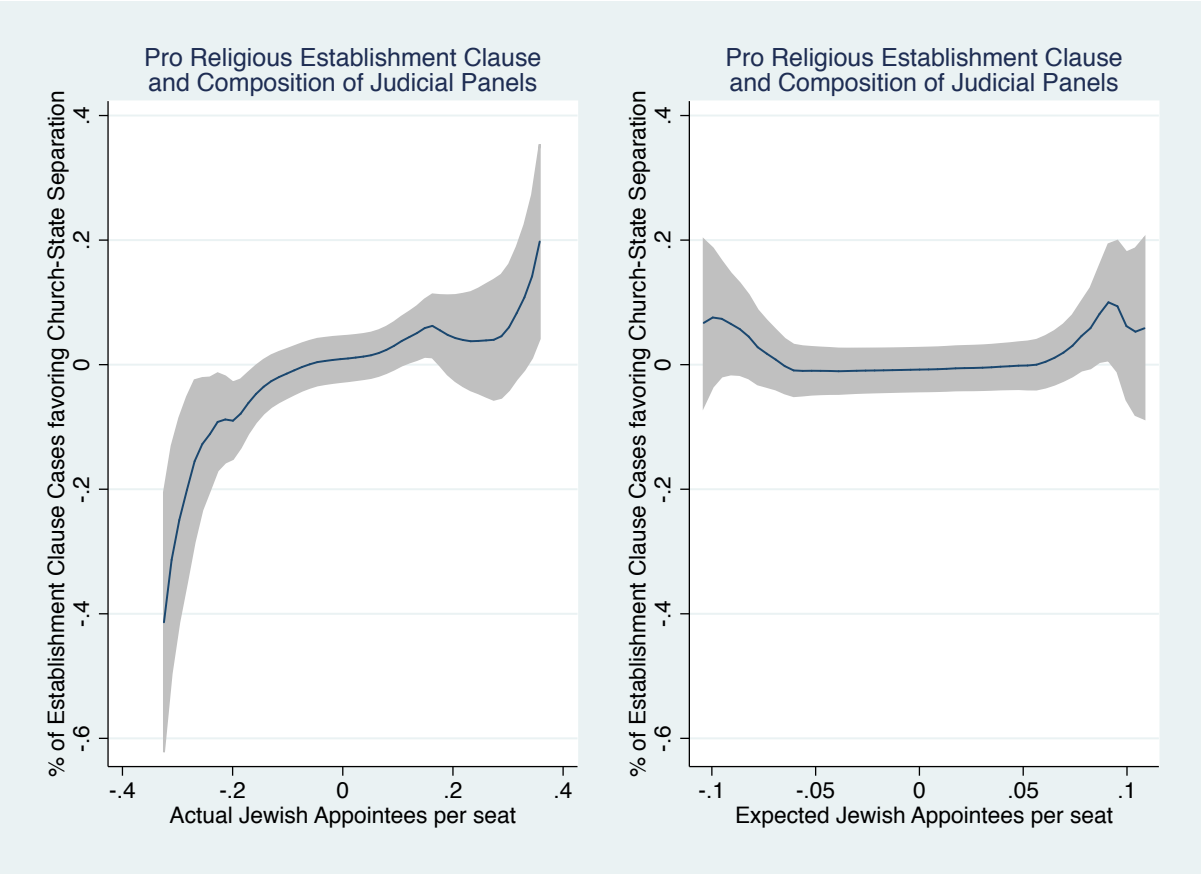


Minority religion judges prefer separate church and state

$$\begin{cases} Law_{ct} = \alpha_{ict} + \phi Z_{ct} + \gamma_1 X_{ict} + \gamma_2 W_{ct} + \eta_{ict} \text{ (machine learning step)} \\ Y_{ict} = \alpha_{ict} + \rho Law_{ct} + \beta_1 X_{ict} + \beta_2 W_{ct} + \varepsilon_{ict} \text{ (causal inference step)} \end{cases}$$

Sparse Models and Methods for Optimal Instruments, Belloni, Chen, Chernuzhukov, Hansen, ECMA 2012

Biographies Predict Votes *What Matters, Chen, Cui, Shang, Zheng, NeurIPS-MLaw 2016*

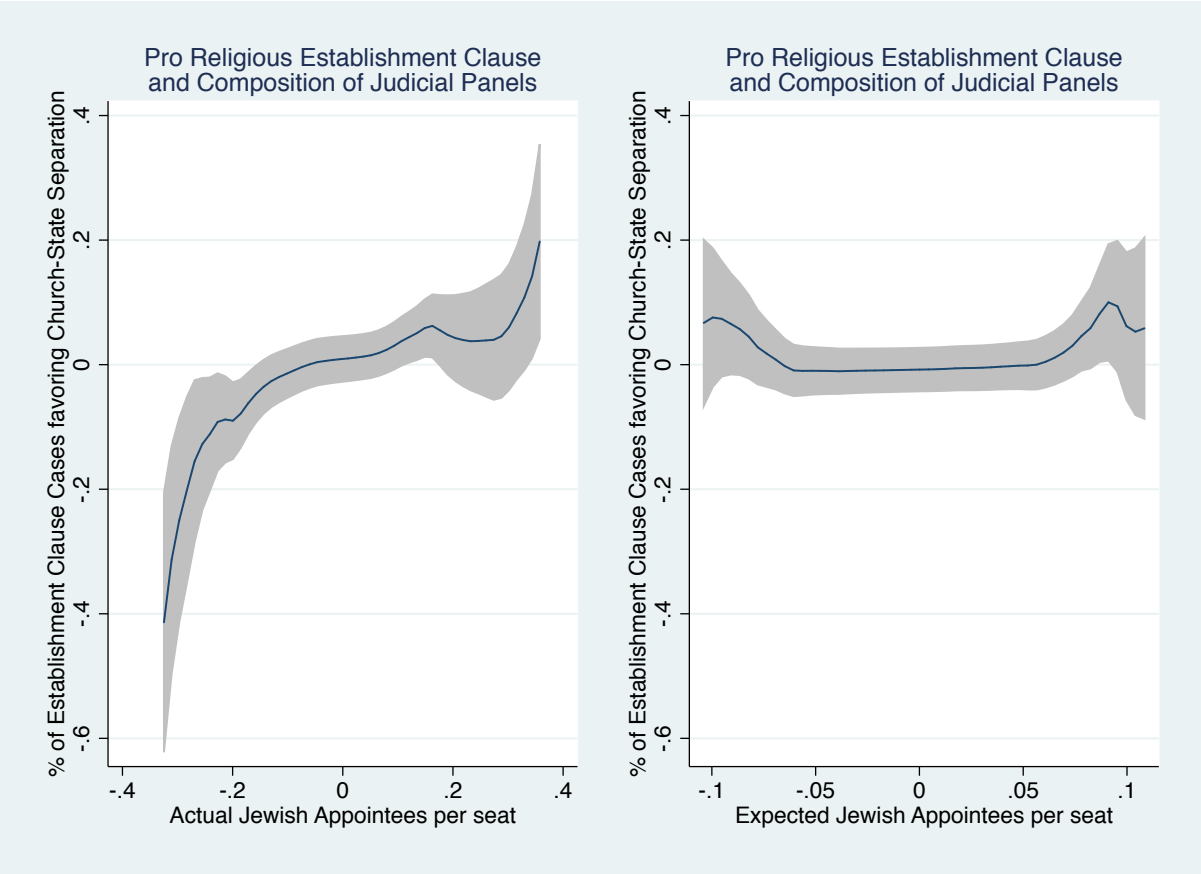


Minority religion judges prefer separate church and state

$$\begin{cases} Law_{ct} = \alpha_{ict} + \phi Z_{ct} + \gamma_1 X_{ict} + \gamma_2 W_{ct} + \eta_{ict} \text{ (machine learning step)} \\ Y_{ict} = \alpha_{ict} + \rho Law_{ct} + \beta_1 X_{ict} + \beta_2 W_{ct} + \varepsilon_{ict} \text{ (causal inference step)} \end{cases}$$

Sparse Models and Methods for Optimal Instruments, Belloni, Chen, Chernuzhukov, Hansen, ECMA 2012

Biographies Predict Votes *What Matters, Chen, Cui, Shang, Zheng, NeurIPS-MLaw 2016*

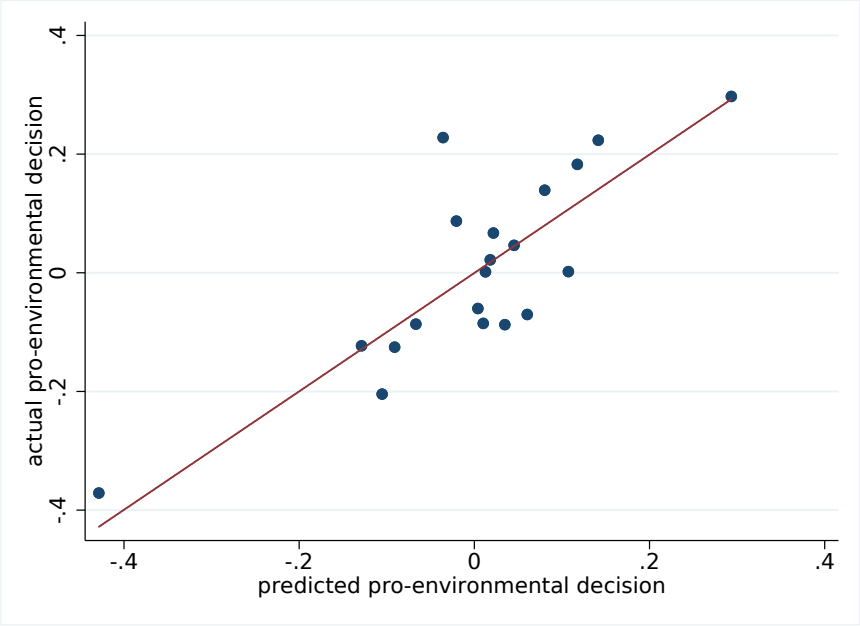


Minority religion judges prefer separate church and state

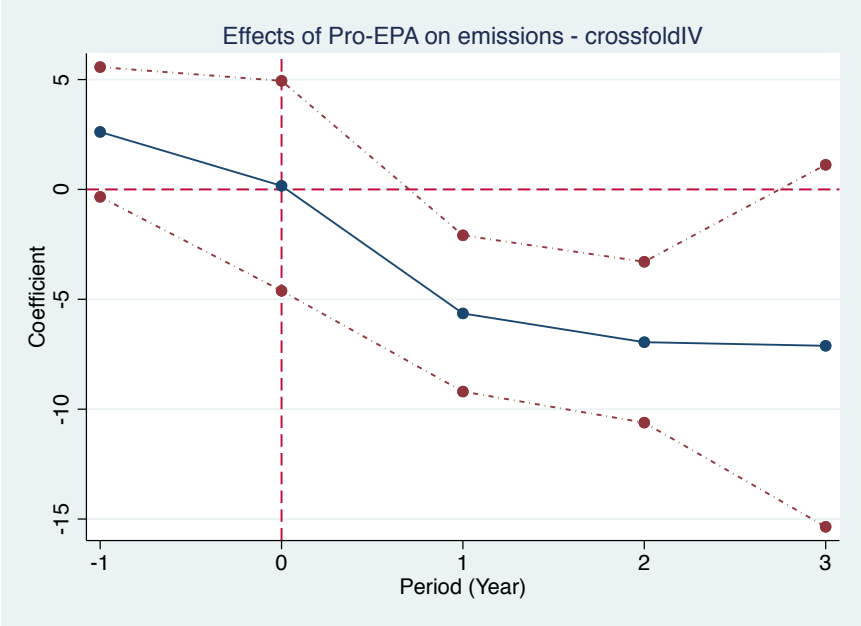
$$\begin{cases} Law_{ct} = \alpha_{ict} + \phi Z_{ct} + \gamma_1 X_{ict} + \gamma_2 W_{ct} + \eta_{ict} \ (\textit{machine learning step}) \\ Y_{ict} = \alpha_{ict} + \rho Law_{ct} + \beta_1 X_{ict} + \beta_2 W_{ct} + \varepsilon_{ict} \ (\textit{causal inference step}) \end{cases}$$

Sparse Models and Methods for Optimal Instruments, Belloni, Chen, Chernuzhukov, Hansen, ECMA 2012

Impact of Environmental Decisions on Pollution

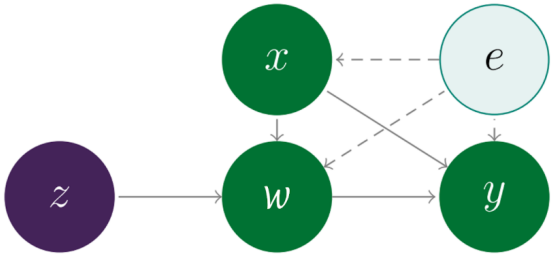


Calibration plot for cross-validated prediction



Rulings in favor of EPA regulations reduce air pollution

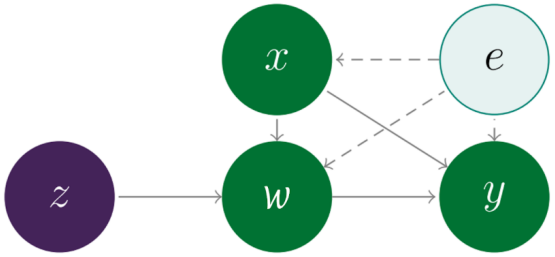
Graphical Model



- District Cases →
- District Judge Bio →
- Circuit Case Appeal →
- **Circuit Judge Characteristics (z) →**
- **Circuit Case Decision (w) →**
- **Precedential Effects (e.g., State Laws) →**
- Promulgation (e.g., News) →
- Outcomes (y)

- Data: All 380K cases, 1,150K judge votes, 94 topics, from 1870s-
  - 700M tokens, 2B 8-grams, 5M citation edges across cases
  - 250 biographical features (D/R, law school, age)
  - 5% sample, 400 hand-coded features; 6K cases hand-coded for meaning in 25 legal areas
  - Link 145K cases out of 2.5M District Court opinions

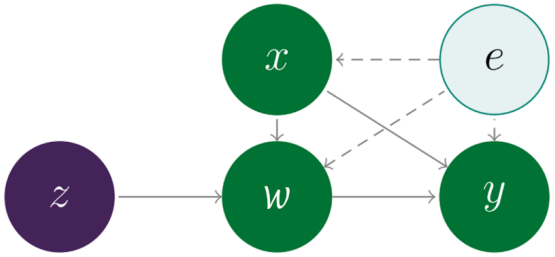
Graphical Model



- District Cases →
- District Judge Bio →
- Circuit Case Appeal →
- **Circuit Judge Characteristics (z) →**
- **Circuit Case Decision (w) →**
- **Precedential Effects (e.g., State Laws) →**
- Promulgation (e.g., News) →
- Outcomes (y)

- Data: All 380K cases, 1,150K judge votes, 94 topics, from 1870s-
  - 700M tokens, 2B 8-grams, 5M citation edges across cases
  - 250 biographical features (D/R, law school, age)
  - 5% sample, 400 hand-coded features; 6K cases hand-coded for meaning in 25 legal areas
  - Link 145K cases out of 2.5M District Court opinions

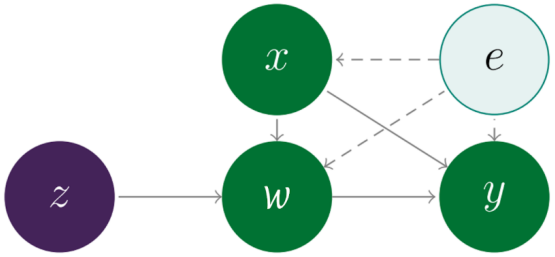
Graphical Model



- District Cases →
- District Judge Bio →
- Circuit Case Appeal →
- **Circuit Judge Characteristics (z) →**
- **Circuit Case Decision (w) →**
- **Precedential Effects (e.g., State Laws) →**
- Promulgation (e.g., News) →
- Outcomes (y)

- Data: All 380K cases, 1,150K judge votes, 94 topics, from 1870s-
  - 700M tokens, 2B 8-grams, 5M citation edges across cases
  - 250 biographical features (D/R, law school, age)
  - 5% sample, 400 hand-coded features; 6K cases hand-coded for meaning in 25 legal areas
  - Link 145K cases out of 2.5M District Court opinions

Graphical Model

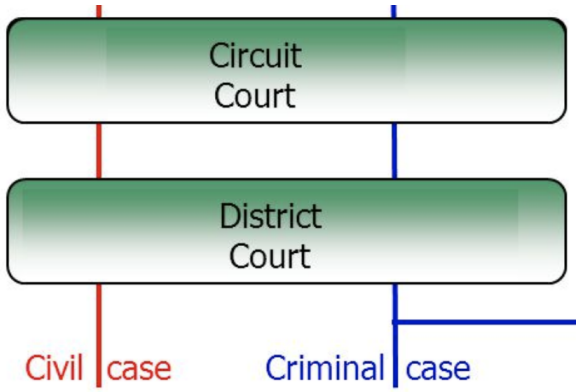


- District Cases →
- District Judge Bio →
- Circuit Case Appeal →
- **Circuit Judge Characteristics (z) →**
- **Circuit Case Decision (w) →**
- **Precedential Effects (e.g., State Laws) →**
- Promulgation (e.g., News) →
- Outcomes (y)

- Data: All 380K cases, 1,150K judge votes, 94 topics, from 1870s-
  - 700M tokens, 2B 8-grams, 5M citation edges across cases
  - 250 biographical features (D/R, law school, age)
  - 5% sample, 400 hand-coded features; 6K cases hand-coded for meaning in 25 legal areas
  - Link 145K cases out of 2.5M District Court opinions

Deep IV (Hartford et al. PMLR 2017)

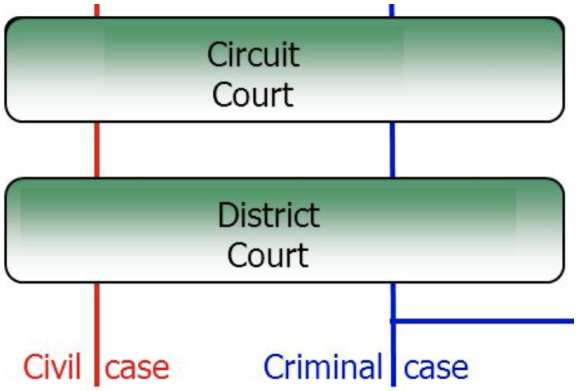
- z: randomly assigned circuit judge characteristics
- w: decisions **and opinions** (7388 cases)
- y: $\triangle$sentencing (3 months before vs. after) in lower district courts
- x: covariates (legal topic)
  - demeaned by fixed effects for circuit and year
- e: confounders correlated with w & y, but not with z



Deep OLS $F(y|w)$, Deep Reduced Form $F(y|z)$, Deep 2SLS

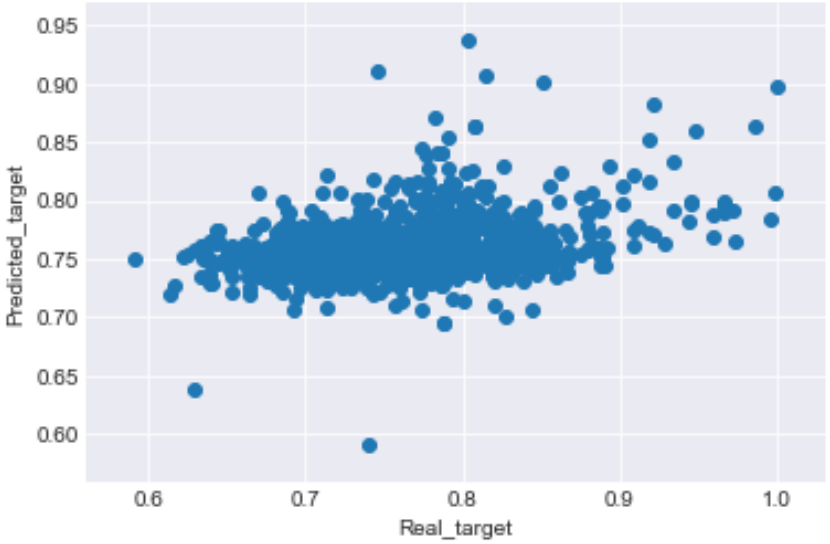
Deep IV (Hartford et al. PMLR 2017)

- z: randomly assigned circuit judge characteristics
- w: decisions **and opinions** (7388 cases)
- y: $\triangle$sentencing (3 months before vs. after) in lower district courts
- x: covariates (legal topic)
  - demeaned by fixed effects for circuit and year
- e: confounders correlated with w & y, but not with z



Deep OLS $F(y|w)$, Deep Reduced Form $F(y|z)$, Deep 2SLS

Deep Reduced Form



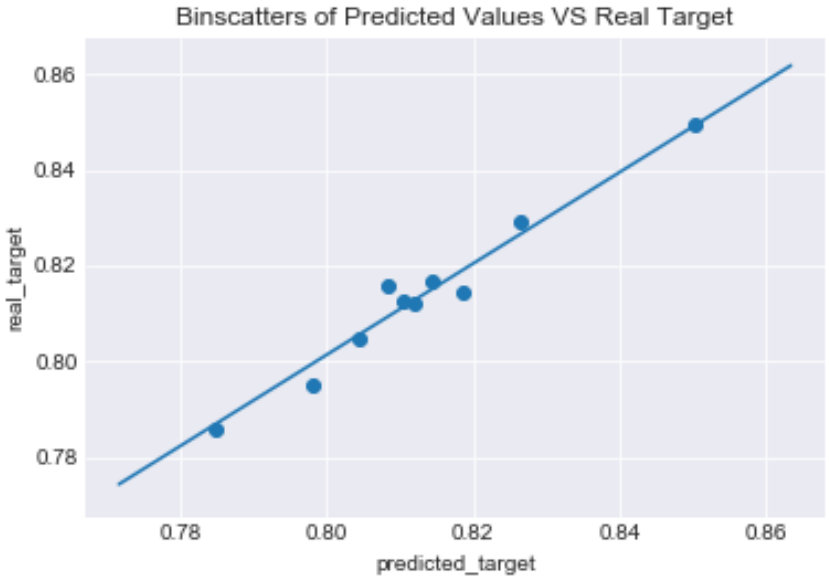


Figure: Predicted vs. Actual Sentence Change

Deep 2SLS

- First stage $F(w|z)$: Predict w using z
  - Represented text using 2 methods
    1. N-Gram Frequencies (TF-IDF adjusted) with PCA
    2. Document Embeddings
  - Random forest regressor to predict (w)
- Second stage $G(y|\hat{w})$: Use the predicted $\hat{w}$ to predict y
  - Neural Network

Deep 2SLS

- First stage $F(w|z)$: Predict w using z
  - Represented text using 2 methods
    1. N-Gram Frequencies (TF-IDF adjusted) with PCA
    2. Document Embeddings
  - Random forest regressor to predict (w)
- Second stage $G(y|\hat{w})$: Use the predicted $\hat{w}$ to predict y
  - Neural Network

Deep First Stage

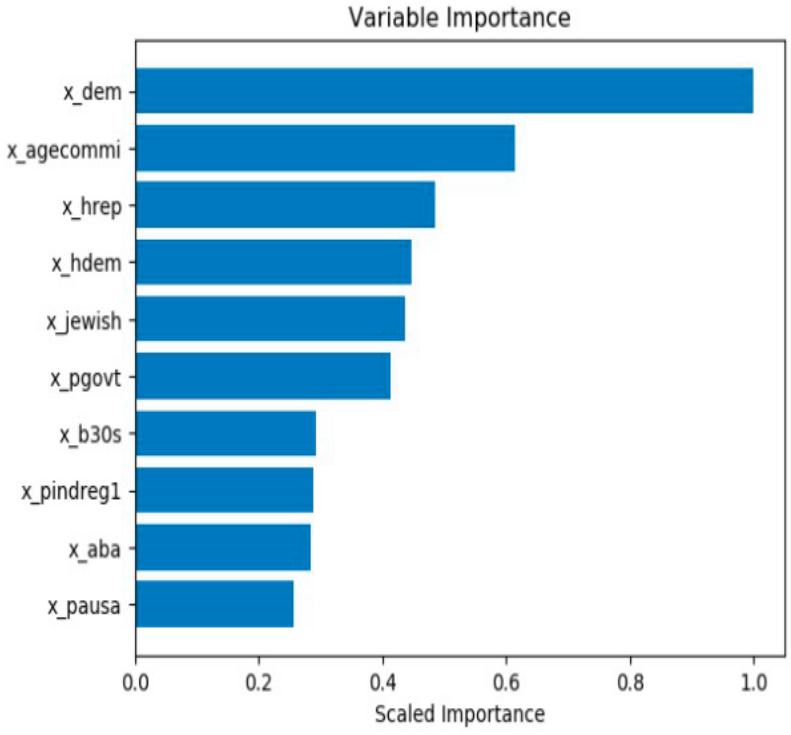


Figure: Feature Importance for Affirm or Reverse

Democrats more lenient: reversing lower-court criminal decisions.

- Predict 25-dimensional doc embedding; judges as input.
  - random forest

Deep First Stage

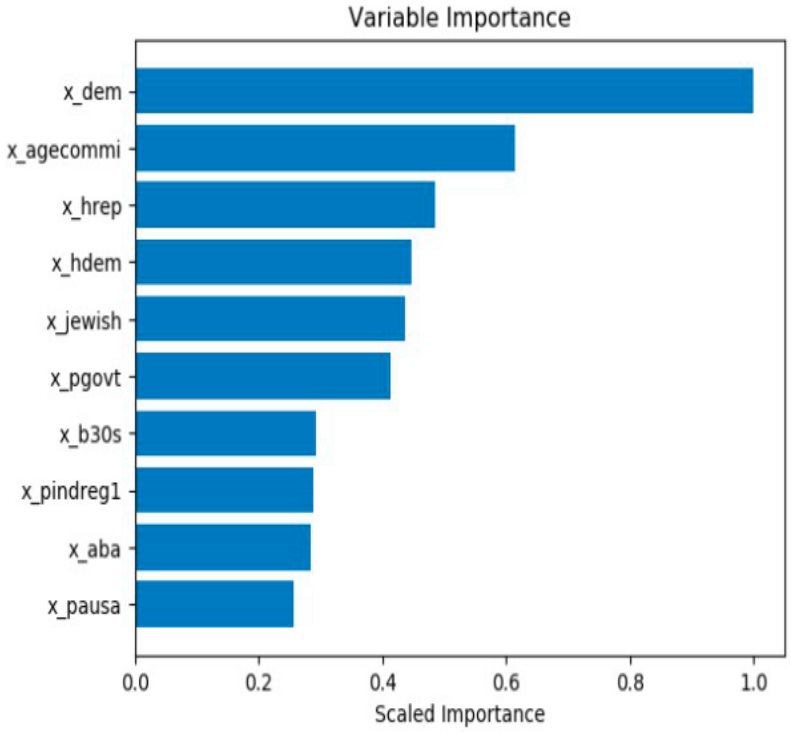


Figure: Feature Importance for Affirm or Reverse

Democrats more lenient: reversing lower-court criminal decisions.

- Predict 25-dimensional doc embedding; judges as input.
  - random forest

Deep 2SLS

- Input into neural network is output of first stage
  - Using the same architecture as DeepOLS, MSE outperforms DeepOLS.
    - ★ Consistent with Deep Reduced Form - judge assignment having signal value
- Reversing a criminal's appeal is weakly correlated with ↑ sentencing
  - Mechanism:
    - ★ Essentially no effect on deviation from sentencing guidelines
    - ★ Prosecutors may adjust charging decisions in response to appellate ruling

Deep 2SLS

- Input into neural network is output of first stage
  - Using the same architecture as DeepOLS, MSE outperforms DeepOLS.
    - Consistent with Deep Reduced Form - judge assignment having signal value
- Reversing a criminal's appeal is weakly correlated with ↑ sentencing
  - Mechanism:
    - Essentially no effect on deviation from sentencing guidelines
    - Prosecutors may adjust charging decisions in response to appellate ruling

Deep 2SLS

- Input into neural network is output of first stage
  - Using the same architecture as DeepOLS, MSE outperforms DeepOLS.
    - Consistent with Deep Reduced Form - judge assignment having signal value
- Reversing a criminal's appeal is weakly correlated with $\uparrow$ sentencing
  - Mechanism:
    - Essentially no effect on deviation from sentencing guidelines
    - Prosecutors may adjust charging decisions in response to appellate ruling

Automated **Prospective** Impact Analysis of Legal Precedents?

- District Cases $\rightarrow$
- District Judge Bio (z_1) $\rightarrow$
- Circuit Case Appeal (w_1) $\rightarrow$
- Circuit Judge Bio (z_2) $\rightarrow$
- **Circuit Case Decision** (w_2) $\rightarrow$
- Precedential Effects (y_1) $\rightarrow$
- Promulgation (y_2) $\rightarrow$
- Outcomes (y_3)
  - 1. **w**: Identifying nearest cases *Learning Policy Levers, Ash, Chen, Degaldo, Fierro, Lin*
  - 2. **w**: Fast decision classification *Automated Fact-Value Distinction, Cao, Ash, Chen*
  - 3. **w**: Document embedding *Case Vectors, Ash, Chen*
  - 4. **z**: Judge embedding using own corpora *...*

Automated **Prospective** Impact Analysis of Legal Precedents?

- District Cases $\rightarrow$
- District Judge Bio (z_1) $\rightarrow$
- Circuit Case Appeal (w_1) $\rightarrow$
- Circuit Judge Bio (z_2) $\rightarrow$
- **Circuit Case Decision** (w_2) $\rightarrow$
- Precedential Effects (y_1) $\rightarrow$
- Promulgation (y_2) $\rightarrow$
- Outcomes (y_3)
  - 1. **w**: Identifying nearest cases *Learning Policy Levers, Ash, Chen, Degaldo, Fierro, Lin*
  - 2. **w**: Fast decision classification *Automated Fact-Value Distinction, Cao, Ash, Chen*
  - 3. **w**: Document embedding *Case Vectors, Ash, Chen*
  - 4. **z**: Judge embedding using own corpora *...*

Automated **Prospective** Impact Analysis of Legal Precedents?

- District Cases $\rightarrow$
- District Judge Bio (z_1) $\rightarrow$
- Circuit Case Appeal (w_1) $\rightarrow$
- Circuit Judge Bio (z_2) $\rightarrow$
- **Circuit Case Decision** (w_2) $\rightarrow$
- Precedential Effects (y_1) $\rightarrow$
- Promulgation (y_2) $\rightarrow$
- Outcomes (y_3)
  - 1. **w**: Identifying nearest cases *Learning Policy Levers, Ash, Chen, Degaldo, Fierro, Lin*
  - 2. **w**: Fast decision classification *Automated Fact-Value Distinction, Cao, Ash, Chen*
  - 3. **w**: Document embedding *Case Vectors, Ash, Chen*
  - 4. **z**: Judge embedding using own corpora ...

Automated **Prospective** Impact Analysis of Legal Precedents?

- District Cases $\rightarrow$
- District Judge Bio (z_1) $\rightarrow$
- Circuit Case Appeal (w_1) $\rightarrow$
- Circuit Judge Bio (z_2) $\rightarrow$
- **Circuit Case Decision** (w_2) $\rightarrow$
- Precedential Effects (y_1) $\rightarrow$
- Promulgation (y_2) $\rightarrow$
- Outcomes (y_3)
  - 1. **w**: Identifying nearest cases *Learning Policy Levers, Ash, Chen, Degaldo, Fierro, Lin*
  - 2. **w**: Fast decision classification *Automated Fact-Value Distinction, Cao, Ash, Chen*
  - 3. **w**: Document embedding *Case Vectors, Ash, Chen*
  - 4. **z**: Judge embedding using own corpora ...

Automated **Prospective** Impact Analysis of Legal Precedents?

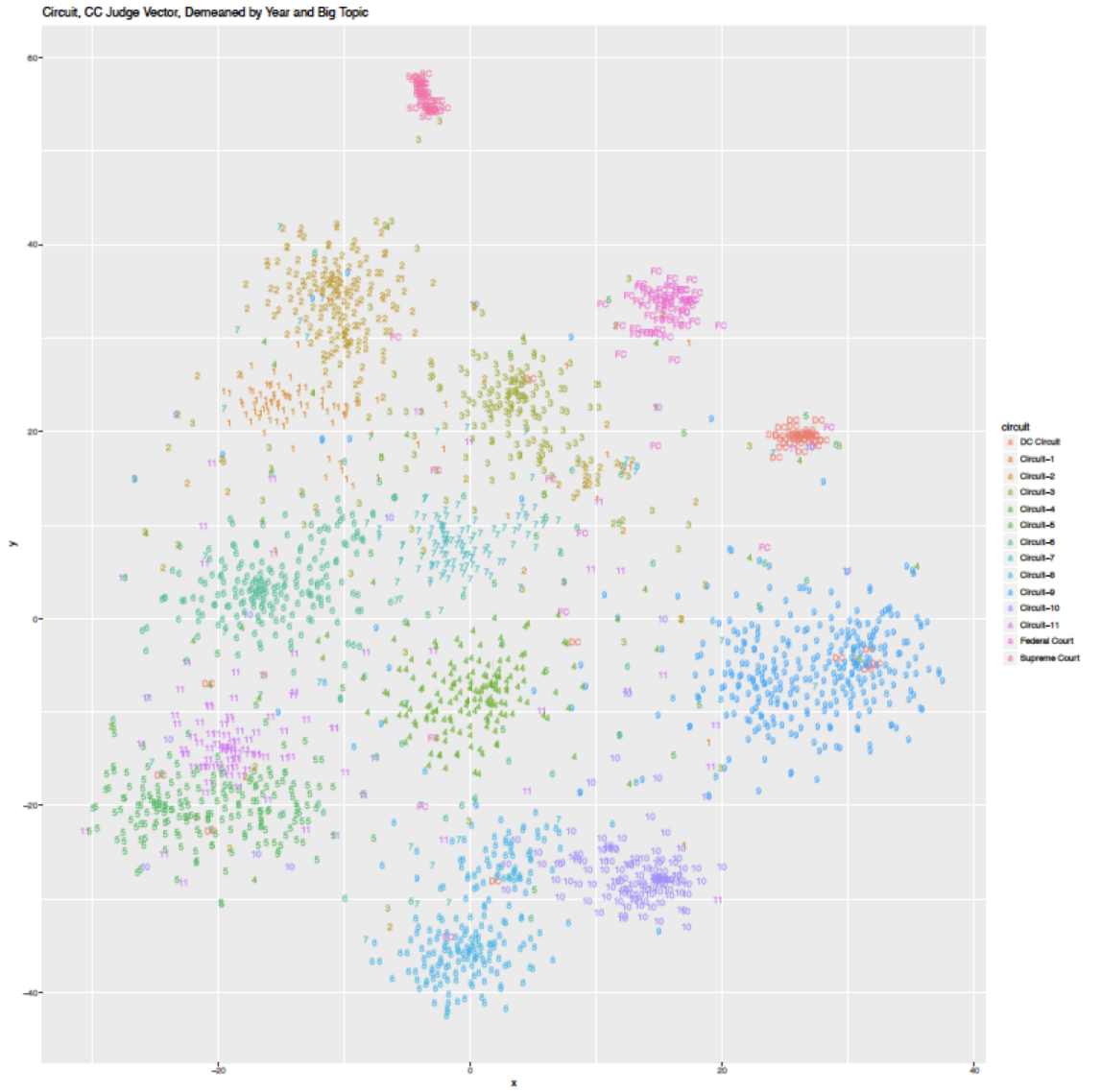
- District Cases $\rightarrow$
- District Judge Bio (z_1) $\rightarrow$
- Circuit Case Appeal (w_1) $\rightarrow$
- Circuit Judge Bio (z_2) $\rightarrow$
- **Circuit Case Decision** (w_2) $\rightarrow$
- Precedential Effects (y_1) $\rightarrow$
- Promulgation (y_2) $\rightarrow$
- Outcomes (y_3)
  - 1. **w**: Identifying nearest cases *Learning Policy Levers, Ash, Chen, Degaldo, Fierro, Lin*
  - 2. **w**: Fast decision classification *Automated Fact-Value Distinction, Cao, Ash, Chen*
  - 3. **w**: Document embedding *Case Vectors, Ash, Chen*
  - 4. **z**: Judge embedding using own corpora ...

Automated **Prospective** Impact Analysis of Legal Precedents?

- District Cases $\rightarrow$
- District Judge Bio (z_1) $\rightarrow$
- Circuit Case Appeal (w_1) $\rightarrow$
- Circuit Judge Bio (z_2) $\rightarrow$
- **Circuit Case Decision** (w_2) $\rightarrow$
- Precedential Effects (y_1) $\rightarrow$
- Promulgation (y_2) $\rightarrow$
- Outcomes (y_3)
  - 1. **w**: Identifying nearest cases *Learning Policy Levers, Ash, Chen, Degaldo, Fierro, Lin*
  - 2. **w**: Fast decision classification *Automated Fact-Value Distinction, Cao, Ash, Chen*
  - 3. **w**: Document embedding *Case Vectors, Ash, Chen*
  - 4. **z**: Judge embedding using own corpora *...*

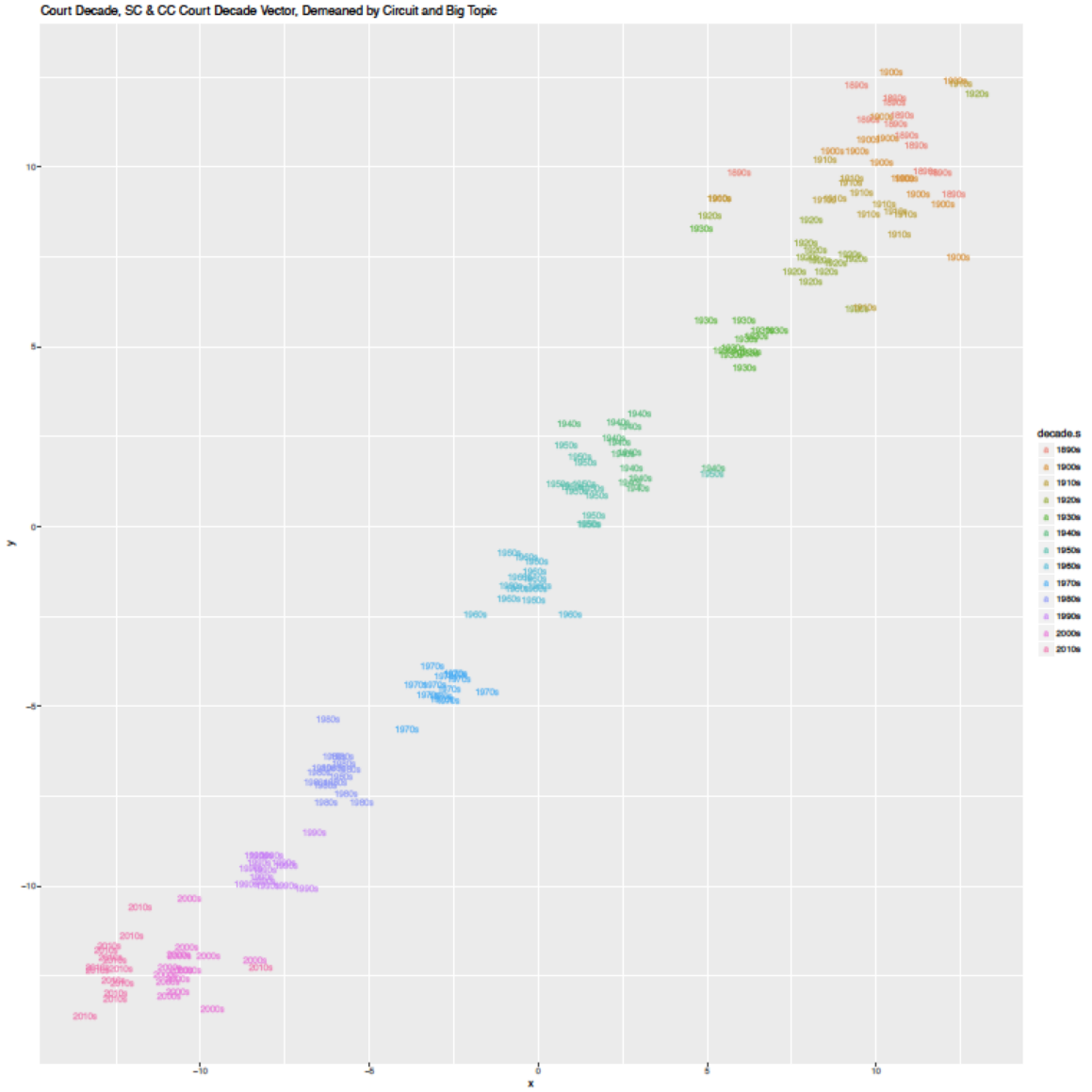
Visual Structure of Case Vectors by Circuit

Figure 1: Centered by Topic-Year, Averaged by Judge, Labeled by Court



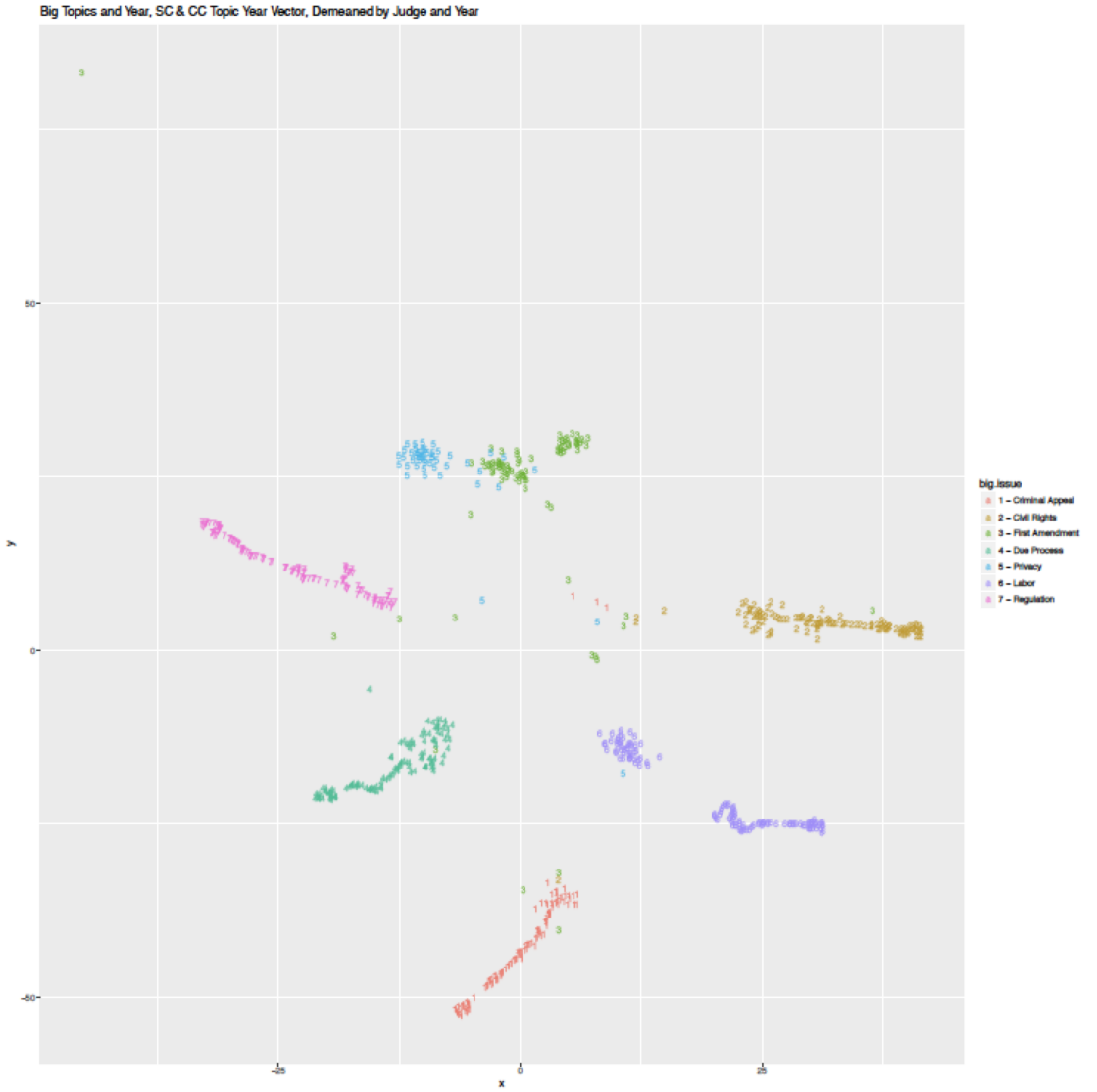
Visual Structure of Case Vectors by Decade

Figure 2: Centered by Court-Topic, Averaged by Court-Year, Labeled by Decade



Visual Structure of Case Vectors by Topic

Figure 3: Centered by Judge-Year, Averaged by Topic-Year, Labeled by Topic

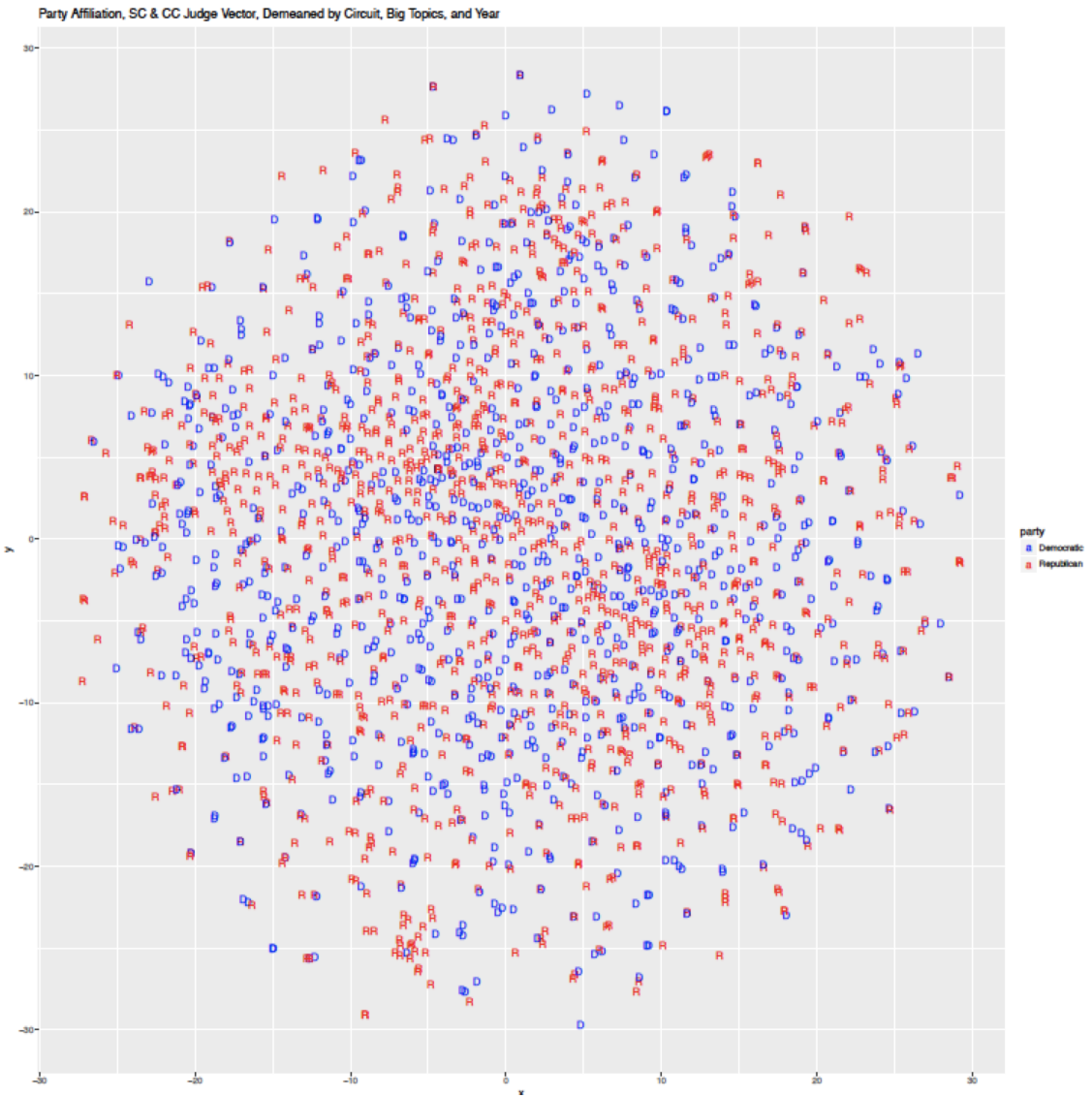


Visual Structure of Case Vectors by Birth Cohort

Figure 5: Centered by Court-Topic-Year, Averaged by Judge, Labeled by Judge Birth Cohort

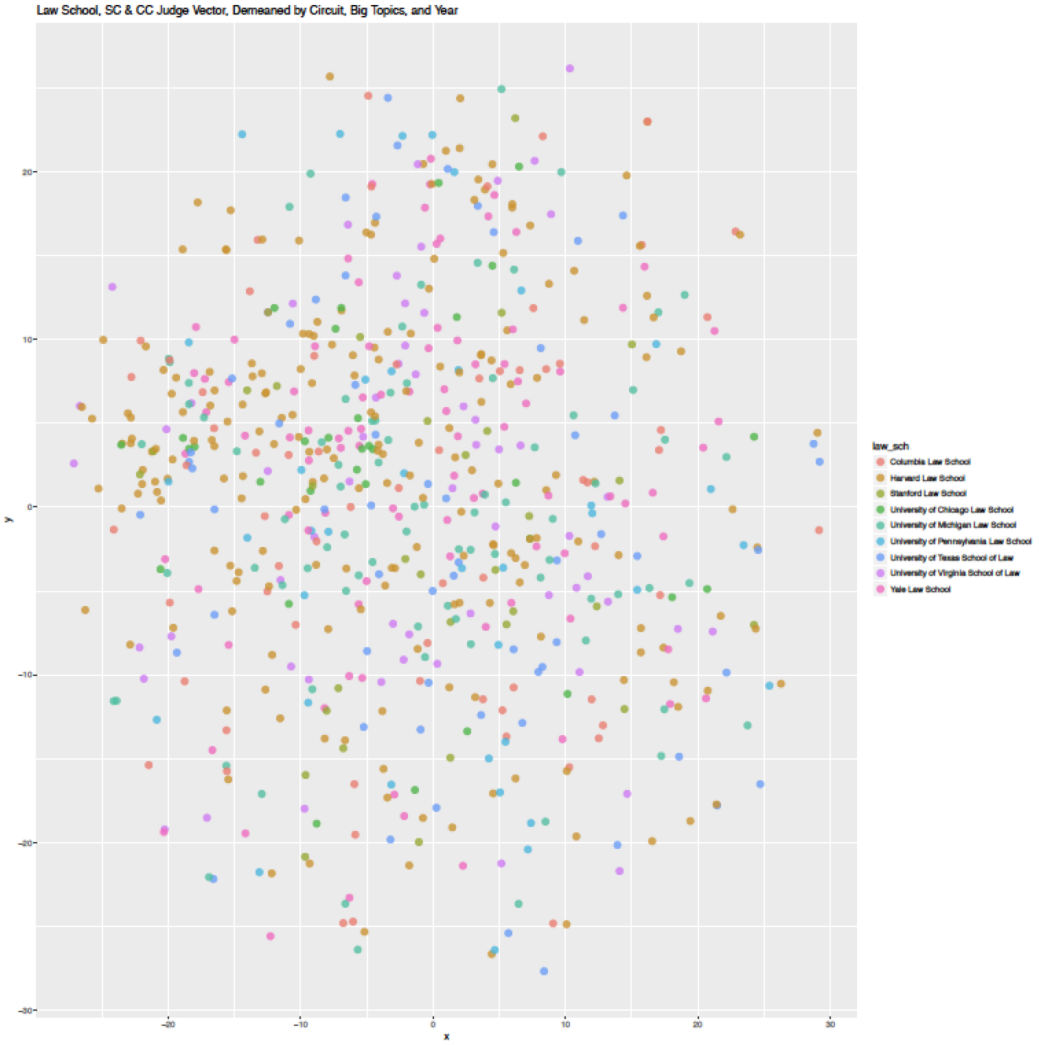
Visual Structure of Case Vectors by Party

Figure 4: Centered by Court-Topic-Year, Averaged by Judge, Labeled by Political Party

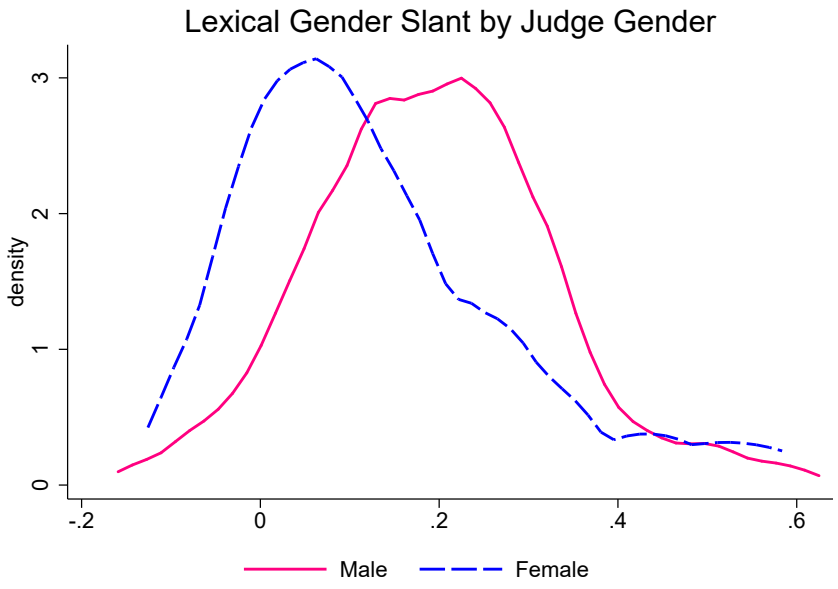


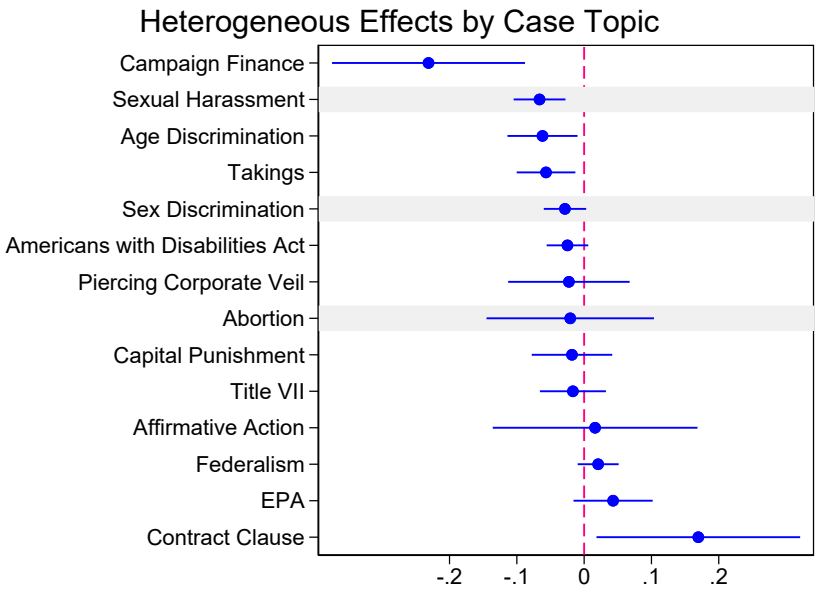
Visual Structure of Case Vectors by Law School

Figure 6: Centered by Court-Topic-Year, Averaged by Judge, Labeled by Law School Attended



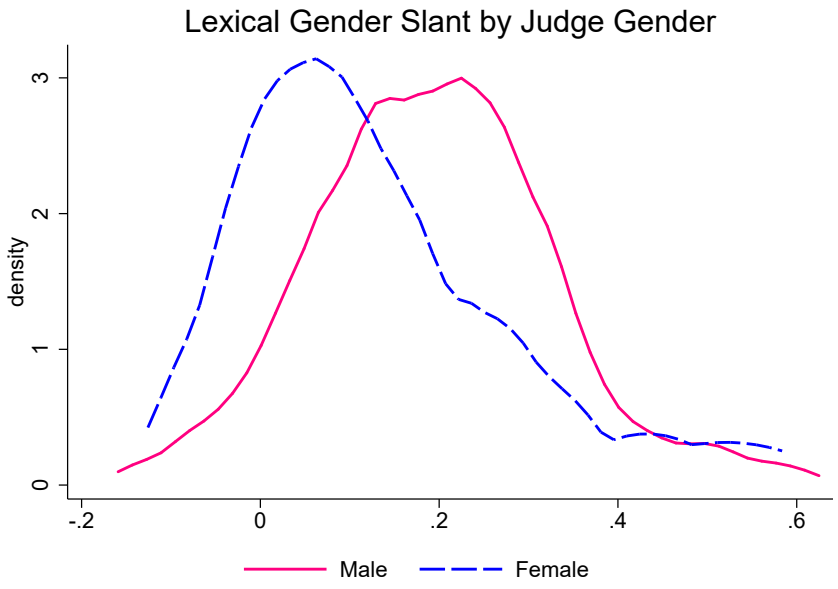
Lexical slant matters in the judiciary *(proxy for IAT using judge's own corpora)*

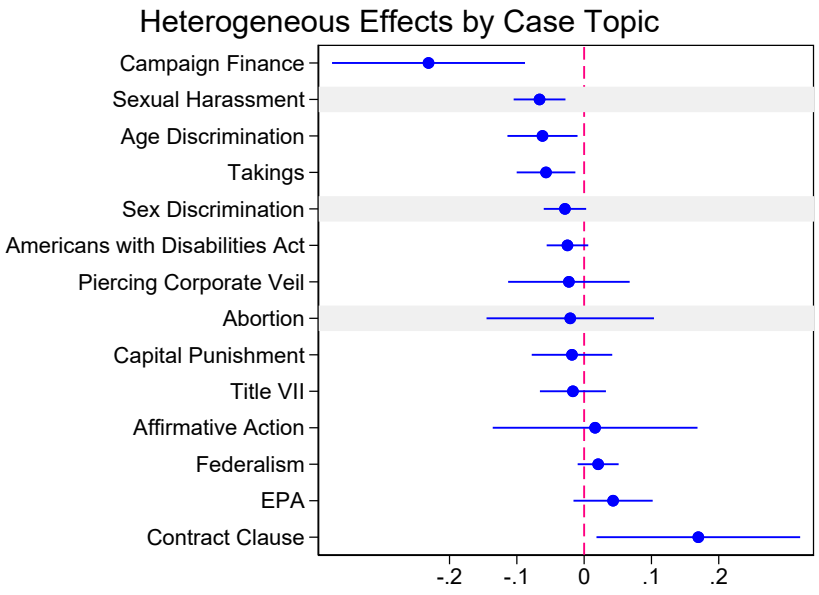




- .. and we still have a long to do list!

Lexical slant matters in the judiciary *(proxy for IAT using judge's own corpora)*





- .. and we still have a long to do list!