Crafting an AI Compass: The Influence of Global AI Standards on Firms

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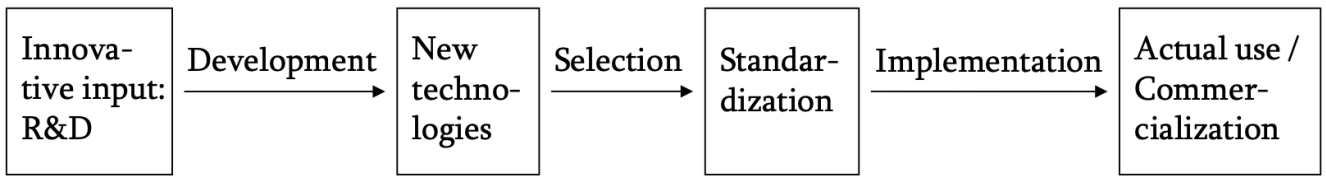
Technological Standardization

- Standardization, the establishment of rules and guidelines for new technologies, is the cornerstone of innovation (Tassey 2017).
  - Once a standard is set, companies operating under its domain are compelled to align their activities accordingly.
    - Ex: Telecommunication standards such as 4G.

Stylized Sequence of Technological Innovation



Source: Figure 4, Baron and Schmidt (2019).

- Standardization contributes to a substantial increase in productivity and GDP growth (Source: ISO).

From Device to AI Standards: A Shift in Focus

- U.S. leadership in AI hinges on federal engagement in setting global standards. (EO 13859 Sections 1(b); 2(d))
  - NIST has issued a plan for global AI standards development.

- Unlike conventional standards, which deal with devices, **AI standards deal with AI systems**.
  - They establish criteria for **data quality**, **training models** and **integrating them into older technologies**, such as manufacturing.
  - They aim to enable **autonomous AI-based systems** to operate in a **transparent, explainable, and fair manner**.

AI Standards: Navigating the Black Box

- Consider a scenario where AI must choose between harming pedestrians or its passengers.
- What technical and ethical criteria should AI follow?
  - Should the AI prioritize the passengers, elderly, or children?

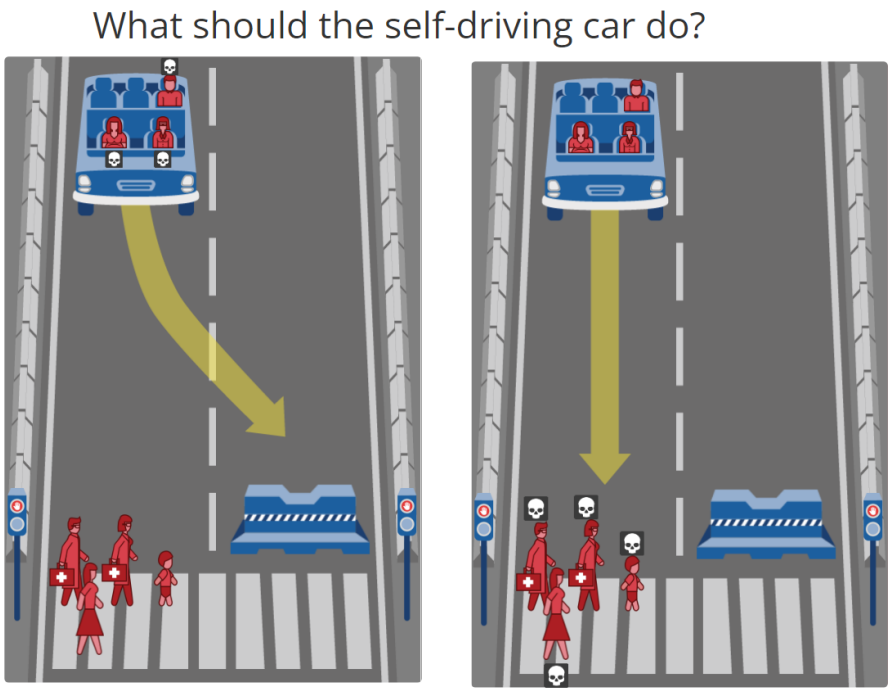


Image taken from the Moral Machine Experiment (Bonnefon, Shariff, and Rahwan 2016).

An Algorithm to Save Lives ...


```
Algorithm: DecideActionForVehicleWithModel
Input: List of objects detected (pedestrians, vehicles, walls, etc.), StatisticalModel

Begin
    Set childDetectedPrediction = False
    Set action = "Save Passengers"
    Set predictionErrorThreshold = 0.10 // Example error threshold

    // Collect features from detected objects
    objectFeatures = ExtractFeatures(List of objects detected)

    // Use the statistical model to predict the likelihood of a child being present
    childPresenceProbability = StatisticalModel.Predict(objectFeatures)

    // Determine if the prediction exceeds the threshold, considering error
    If childPresenceProbability > (0.50 + predictionErrorThreshold) then
        Set childDetectedPrediction = True
    End If

    // Decide action based on the prediction
    If childDetectedPrediction == True then
        Set action = "Swerve and Hit Wall"
    Else
        Set action = "Save Passengers"
    End If

    Return action
End

Function: ExtractFeatures(objects)
    // Process the list of objects and extract relevant features for the model
    // This can include size, shape, movement patterns, etc.
    // Return a structured format of features
End Function
```

... Will Depend on AI Standards


```
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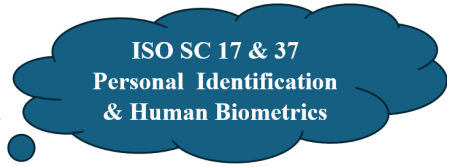

Key Research Questions Explored

- Impact of AI standards on AI investments and AI patents
  - 36 investment categories and 22 patent categories.
- Influence of AI standards on corporate investment, R&D, and value
  - Types of standards (e.g., technical vs. ethical)
  - Involvement by country (e.g., standardization leaders, contributors)

Key Research Questions Explored

- Impact of AI standards on AI investments and AI patents
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- Influence of AI standards on corporate investment, R&D, and value
  - Types of standards (e.g., technical vs. ethical)
  - Involvement by country (e.g., standardization leaders, contributors)
- Empirically, the influence of AI standards on firm outcomes is not clear ex ante.
  - On the positive side, standards encourage corporate investment by reducing uncertainty and introducing a positive productivity shock.
  - On the flip side, they may stifle radical innovation and increase royalties, leaving less money for investment.
    - Ex: Qualcomm vs. FTC; 5G SEP wars.

Summary of Findings

- **Influence on Investments**:
  - Adoption of AI standards leads to significant increases in AI-specific and broader investment and R&D activities.
- **Impact on Firm Value**:
  - An increase in AI standards is associated with a growing influence on firm value over time.
- **Effect Heterogeneity**:
  - Technical standards boost investment; ethical standards reduce it.
  - Secretariats benefit most, followed by contributors, then other countries.
- **Policy Implications**:
  - Identify committees beneficial or detrimental to U.S. and other policymakers' interests.

Related Literature

- AI and investment: Aghion, Jones, and Jones 2018 and Babina et al. 2021.
- Data economy and privacy: Begenau, Farboodi, and Veldkamp 2018, Cong, Xie, and Zhang 2021, Canayaz, Kantorovitch, and Mihet 2022.
- Ethical AI and AI regulations: Wellman and Rajan 2017, Agrawal, Gans, and Goldfarb 2019, Clark and Hadfield 2019, Acemoglu 2021, Cuéllar et al. 2022.
- Applications of AI Tech in Finance: Cao et al. 2020, D'Acunto, Prabhala, and Rossi 2019.
- Standard-setting organizations: Lerner and Tirole 2006, Chiao, Lerner, and Tirole 2007, Simcoe 2012.
- Standardization and innovation: Lerner and Tirole 2014, and Baron and Schmidt 2019.

Key Contributions

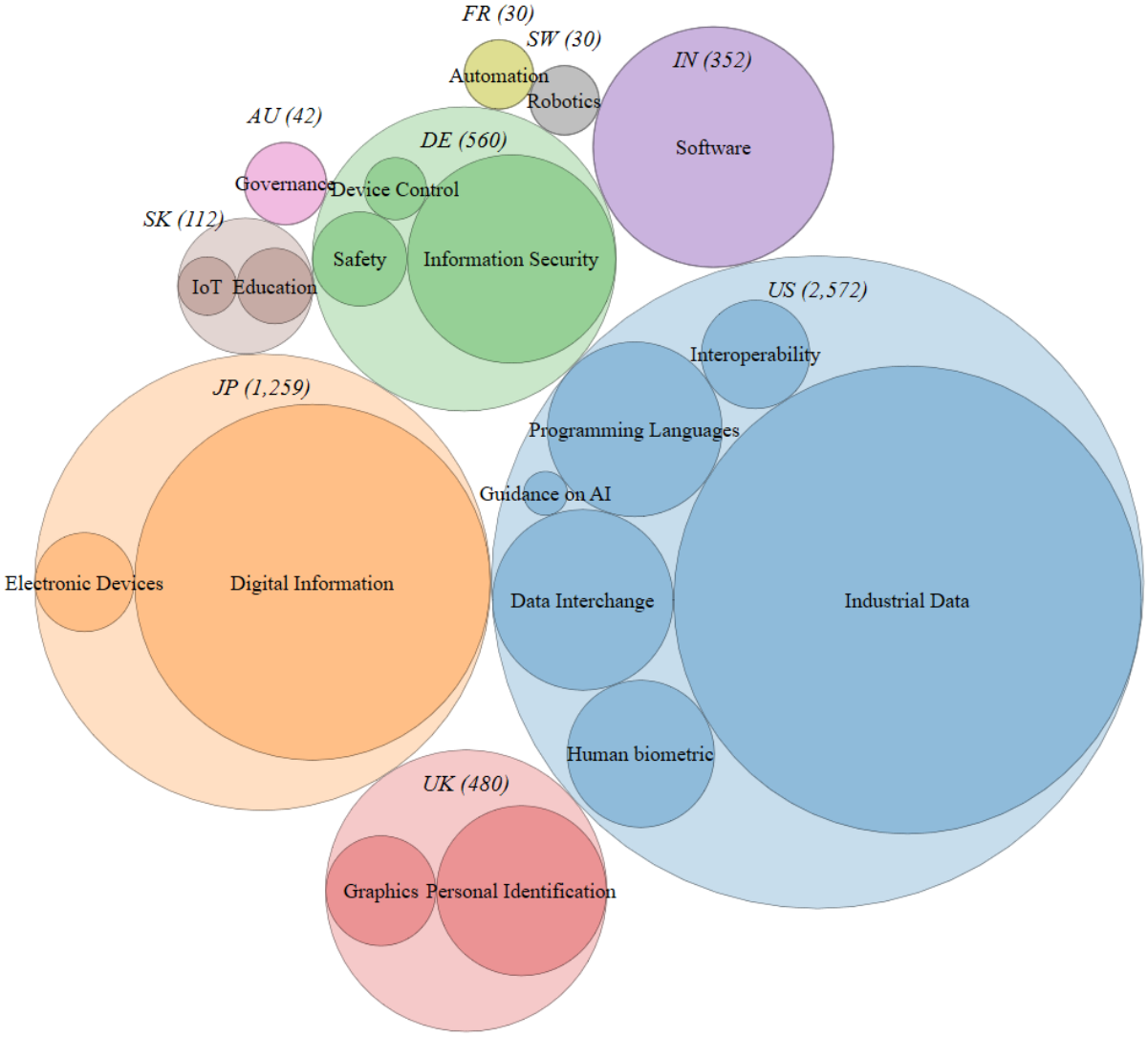
- First analysis of global AI standard setting with a unique, hand-collected dataset of standards and committees.
  - We collect data on based on critical AI committees identified in NIST's report, 'U.S. Leadership in AI: A Plan for Federal Engagement in Developing Technical Standards and Related Tools,' in response to EO 13859.
- First study to explore the impact of AI standardization on AI-related investments, AI patenting, and broader firm investment and valuation outcomes.
  - Utilize textual analysis to classify AI standards into a rich array of technical and ethical standard categories.

Standard Publishing Process

- AI standardization process follows a model similar to the paper publishing model in academia.

- Each secretariat country aims to shape AI standards to benefit its interests (see, e.g., EO 13859 'Maintaining American Leadership in Artificial Intelligence').
  - **Supportive committee members are key, as they vote on standards critical to advancing any agenda.**
  - **More favorable committee members $\rightarrow$ more standards.**

Exogenous Variation in the % of Favorable Committee Members



Identification Strategy

- Rotations in the UN Security Council (UNSC) can affect permanent members' ability to publish standards.
  - Permanent members are known to gain policy support by incentivizing rotating members with 'donations' (Kuziemko and Werker 2006).
    - Example: Turkey as a rotating UNSC member in 2018 would receive more U.S. 'donations' and support U.S. AI agendas, increasing favorable countries.
    - Conversely, Iran's UNSC membership without U.S. committee involvement would decrease support next round.
    - **Random, 2-year UNSC rotations make it hard for countries to strategically time their membership in U.S. AI committees.**
- 'Treated' countries: US, UK, France.
- 'Control' countries: All others.

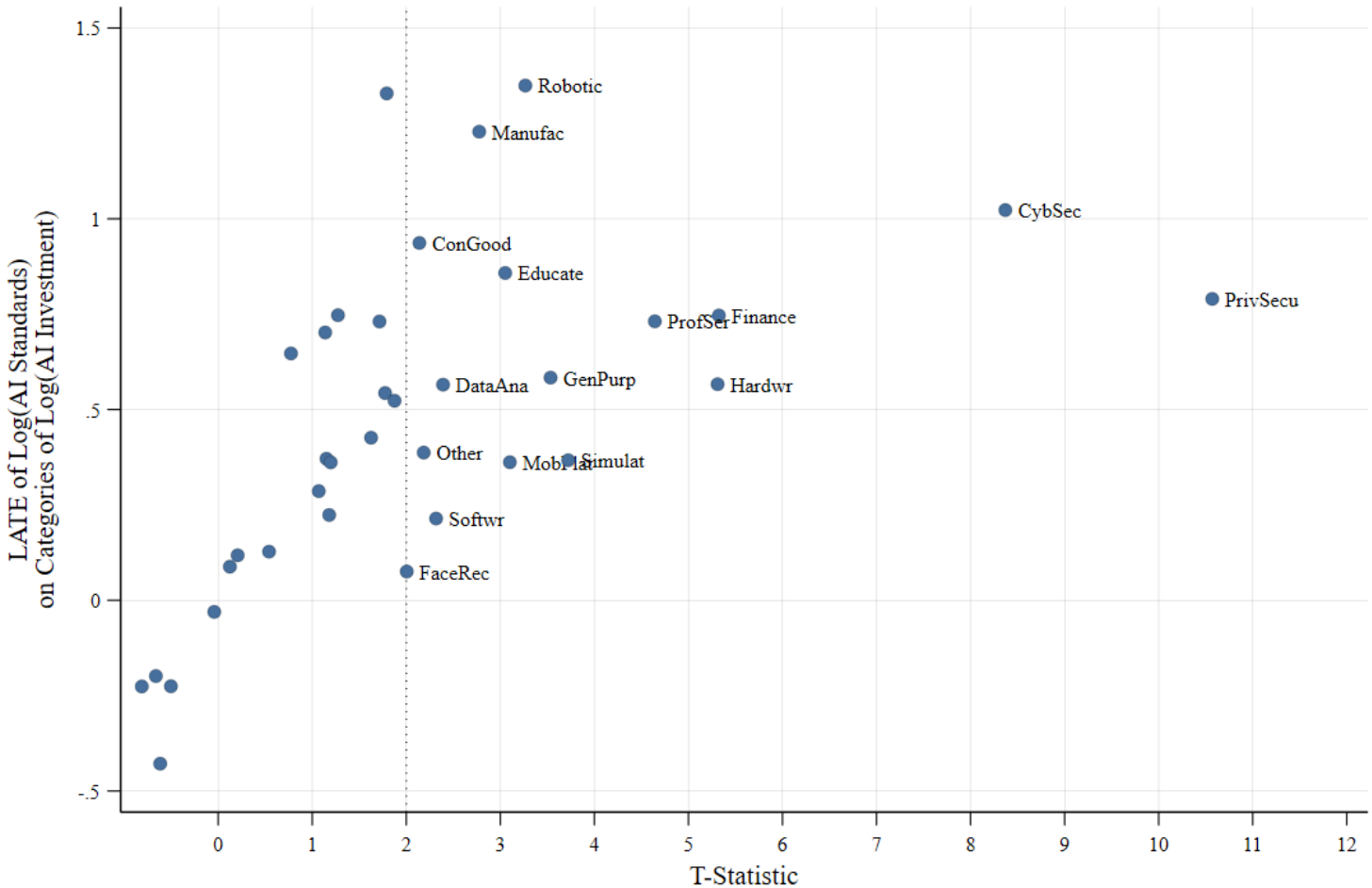
The Effect of AI Standards on Firm-Level Investment

- We empirically estimate the effects of AI standards on investment activity using a 2SLS procedure.

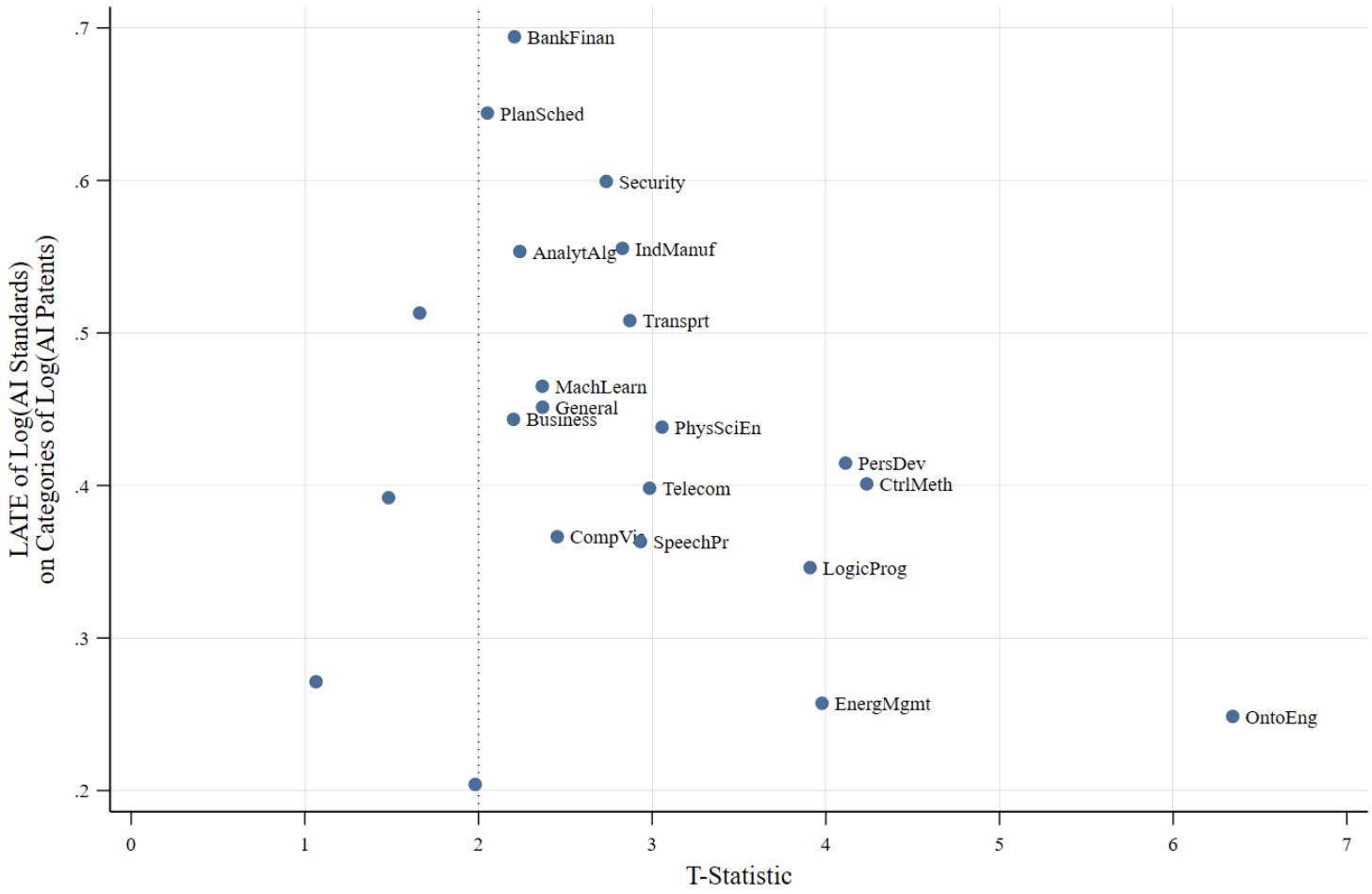
$$y_{i,c,t} = \beta_0 + \beta_1 \overbrace{Log(AI\ Standards_{i,c,t})}^{\text{IV: } \textbf{\%UNSC Members}_{i,c,t-1}} + \gamma X_{i,c,t-1} + \tau W_{c,t-1} + \text{FEs} + \epsilon_{i,c,t}, \quad (1)$$

  - $y_{i,c,t}$ refers to capital or R&D expenditures to lagged assets of firm i from country c in year t.
  - $Log(AI\ Standards_{i,c,t})$ is the logarithm of the number of AI Standards published by country c of firm i in year t.
- The idea is that permanent UN Security Council members pay rotating members for policy support including AI agendas (Kuziemko and Werker 2006).

AI Standards and AI Investment Categories



AI Standards and AI Patent Categories



Firm-Level Investment and R&D

	$CAPEX/AT_{i,c,t}$	$CAPEX/AT_{i,c,t}$	$RD/AT_{i,c,t}$	$RD/AT_{i,c,t}$
$Log(AI\ \widehat{Standards}_{i,c,t})$	0.48***	0.50***	1.86***	1.65***
	(4.65)	(3.80)	(9.46)	(4.88)
Controls	Yes	Yes	Yes	Yes
Fixed Effects				
Firm	Yes	Yes	Yes	Yes
Year	Yes	No	Yes	No
Industry $\times$ Year	No	Yes	No	Yes
Observations	171,238	171,238	67,654	67,647
F-stat (Excl. Inst.)	66.10	63.68	97.02	93.12
$\sqrt{c_{0.05}(F)}$	2.06	2.07	1.97	1.98
$\sqrt{c_{0.01}(F)}$	3.26	3.28	3.05	3.06

Firm-Level Valuation Ratios

	$Log(M/B_{i,c,t+1})$	$Log(M/B_{i,c,t+1})$	$Log(Q_{i,c,t+1})$	$Log(Q_{i,c,t+1})$
	(1)	(2)	(3)	(4)
$Log(AI\ \widehat{Standards}_{i,c,t})$	3.67%**	2.84%**	3.60%***	3.08%**
	(2.25)	(2.08)	(2.93)	(2.74)
Controls	Yes	Yes	Yes	Yes
Fixed Effects				
Firm	Yes	Yes	Yes	Yes
Year	Yes	No	Yes	No
Industry × Year	No	Yes	No	Yes
Observations	134,353	134,352	134,252	134,251
F-stat (Excl. Inst.)	66.10	63.68	97.02	93.12
$\sqrt{c_{0.05}(F)}$	2.14	2.15	2.13	2.15
$\sqrt{c_{0.01}(F)}$	3.47	3.48	3.44	3.48

Evidence on Effect Heterogeneity

- We provide three types of effect heterogeneity:
  - **By committees:** Uses % UNSC at the country-committee level and includes placebo tests on cross-committee UNSC percentages.
  - **By standards:** NLP identifies topics when different committees produce standards on the same subject.
  - **By leader and contributor countries:** Measures, e.g., the effect of US standards on US firms relative to firms from specific European, Asian, etc. countries.

Effect Heterogeneity: AI Committee Types

Results are based on **committee-level** variation in % UNSC members.

Panel A: Groups of Treatment and Control Units Based on ISO Committees

	(Group 1)	(Group 2)	(Group 3)	(Group 4)	(Group 5)	(Group 6)
Committee	SC 4	SC 5	SC 22	SC 32	SC 37	SC 42
Scope	Industrial data	Interoperability	Prog. Lang.	Data Interchange	Biometrics	Guidance on AI
Organization	ISO/TC 184	ISO/TC 184	ISO/IEC JTC 1	ISO/IEC JTC 1	ISO/IEC JTC 1	ISO/IEC JTC 1
Secretariat	United States	United States	United States	United States	United States	United States

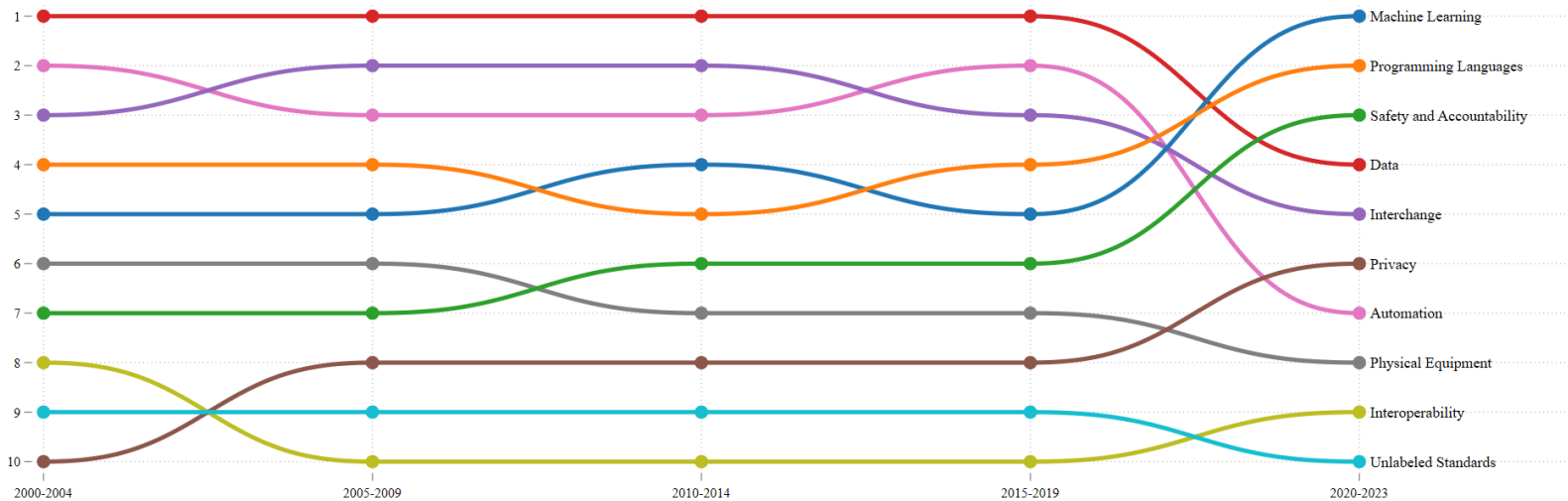
Panel B: ISO Committees and Capital Expenditures (N= 171,238)

	(Group 1)	(Group 2)	(Group 3)	(Group 4)	(Group 5)	(Group 6)
Dependent Variable						
$CAPEX/AT_{i,c,t}$	0.16**	0.11	1.27***	-0.86***	-0.36	-0.78***
	(2.56)	(0.52)	(5.60)	(-5.02)	(-0.60)	(-5.26)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: ISO Committees and R&D Expenditures (N= 67,647)

	(Group 1)	(Group 2)	(Group 3)	(Group 4)	(Group 5)	(Group 6)
Dependent Variable						
$RD/AT_{i,c,t}$	0.34***	1.85***	3.27***	-1.52***	-1.54*	-1.91***
	(4.57)	(7.14)	(5.98)	(-7.05)	(-1.89)	(-7.25)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard Types Based on Textual Analysis



- Popular standards include ML, programming languages, safety, accountability, and data.
- Data standards now emphasize privacy and accountability over technical aspects.
- Automation standards have declined in popularity.

Effect Heterogeneity: Standard Types

Panel A: AI-Standard Categories and Capital Expenditures (N=171,238)

	Machine Learning Standards	Data Standards	Automation Standards	Interchange Standards	Machinery & Equipment Standards	Privacy Standards
	(1)	(2)	(3)	(5)	(6)	(8)
Dep. Var.: $CAPEX/AT_{i,c,t}$	1.58**	0.27***	0.30***	0.31***	0.28***	-2.76
	(2.11)	(3.50)	(2.96)	(3.04)	(3.82)	(-1.62)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: AI-Standard Categories and R&D Expenditures (N=67,647)

	Machine Learning Standards	Data Standards	Automation Standards	Interchange Standards	Machinery & Equipment Standards	Privacy Standards
	(1)	(2)	(3)	(5)	(6)	(8)
Dep. Var.: $RD/AT_{i,c,t}$	5.17	0.86***	0.96***	1.00***	0.93***	-9.36**
	(1.62)	(5.15)	(5.03)	(5.03)	(5.08)	(-2.35)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Conclusion

- **Influence on Investments**:
  - Adoption of AI standards leads to significant increases in AI-specific and broader investment and R&D activities.
- **Impact on Firm Value**:
  - An increase in AI standards is associated with a growing influence on firm value over time.
- **Effect Heterogeneity**:
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  - Secretariats benefit most, followed by contributors, then other countries.
- **Policy Implications**:
  - Identify committees beneficial or detrimental to U.S. and other policymakers' interests.

Appendix

Theory: Model

I One firm, infinite horizon, discrete time.

II N domains of AI investment, each has two types of AI tech (A, B).

III At the start of period t, firm makes AI-investment in domain n and of type i, and physical investment

IV Disinvestment is costly

V Capital stock of AI tech at the end of period t:

$$AI_t \equiv \sum_{n=1}^{N} \left(\tilde{s}_t^{n,A} F(AI_t^{n,A}) + \tilde{s}_t^{n,B} F(AI_t^{n,B}) \right)$$

i $\tilde{s}_t^{n,A}$: productivity of AI-tech i in domain n

ii $AI_t^{n,i}$: capital stocks of AI-tech i in domain n

Theory: Model

I Output in period t:

$$Y_t = AI_t^{\alpha} K_t^{1-\alpha} D(1 - \tilde{\tau}_t)$$

i AI_t: AI capital stock; K_t: physical capital stock

ii D: data input

iii $\tilde{\tau}_t \in [0, 1)$: limitations on data privacy/ethical use of AI

Theory: Model

- Firm's investment problem at the start of period $j \geq 1$:

$$\max_{\{I^{n,A}_{AI,t}, I^{n,B}_{AI,t}, I_{K,t}\}_{t=j}^{\infty}} \mathbb{E} \sum_{t=j}^{\infty} \beta^{t-1} \Big\{ AI_t^{\alpha} K_t^{1-\alpha} D(1-\tilde{\tau}_t)$$

$$- \sum_{n=1}^{N} \left(CI_n(I^{n,A}_{AI,t}) + CI_n(I^{n,B}_{AI,t}) \right) - CI_K(I_{K,t}) \Big\}$$

$$s.t. \text{(capital dynamics)}\ AI_t^{n,i} = AI_{t-1}^{n,i} + I^{n,i}_{AI,t}$$

$$K_t = K_{t-1} + I_{K,t}.$$

$$\text{(costly disinvestment)}\ CI_n(I) = \begin{cases} I & \text{if } I \geq 0 \\ C^n I & \text{if } I < 0 \end{cases}$$

$$CI_K(I) = \begin{cases} I & \text{if } I \geq 0 \\ C^K I & \text{if } I < 0 \end{cases}$$

$$C^n, C^K \in (0,1)$$

Theory: Model

I Firm expects one AI standard publication event with Poisson arrival. Conditional on arrival:

II With π, only tech standards can be published. Standard of domain n bifurcates the two AI techs in that domain:

- If type i is endorsed, then type i productivity $\tilde{s}_t^{n,i}$ increases to several times its pre-publication value, and type $-i$ productivity $\tilde{s}_t^{n,-i}$ decreases to a portion of its initial value.
- The tech standard of domain n is published with prob q, i.i.d. across N domains.

III With $1-\pi$, only privacy/ethical standards can be published, increasing the limitations on AI techs:

- If m_e such standards are published, limitation $\tilde{\tau}_t$ increases from 0 to $\tau(m_e)$, $\tau' > 0$.
- Each standards is published with prob q_e, i.i.d. across N_e possible standards.

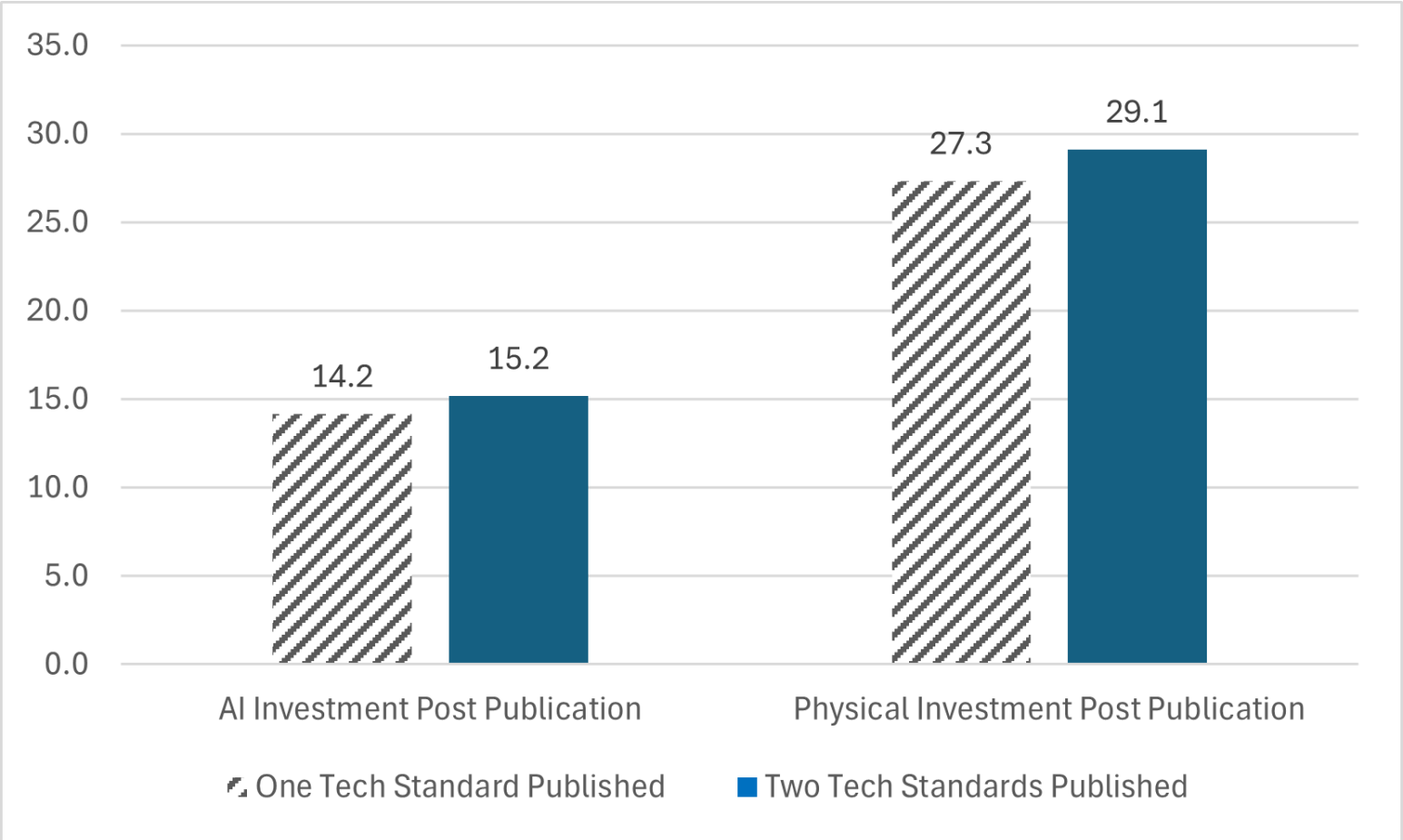
Theory: Empirical Implications

Hypothesis

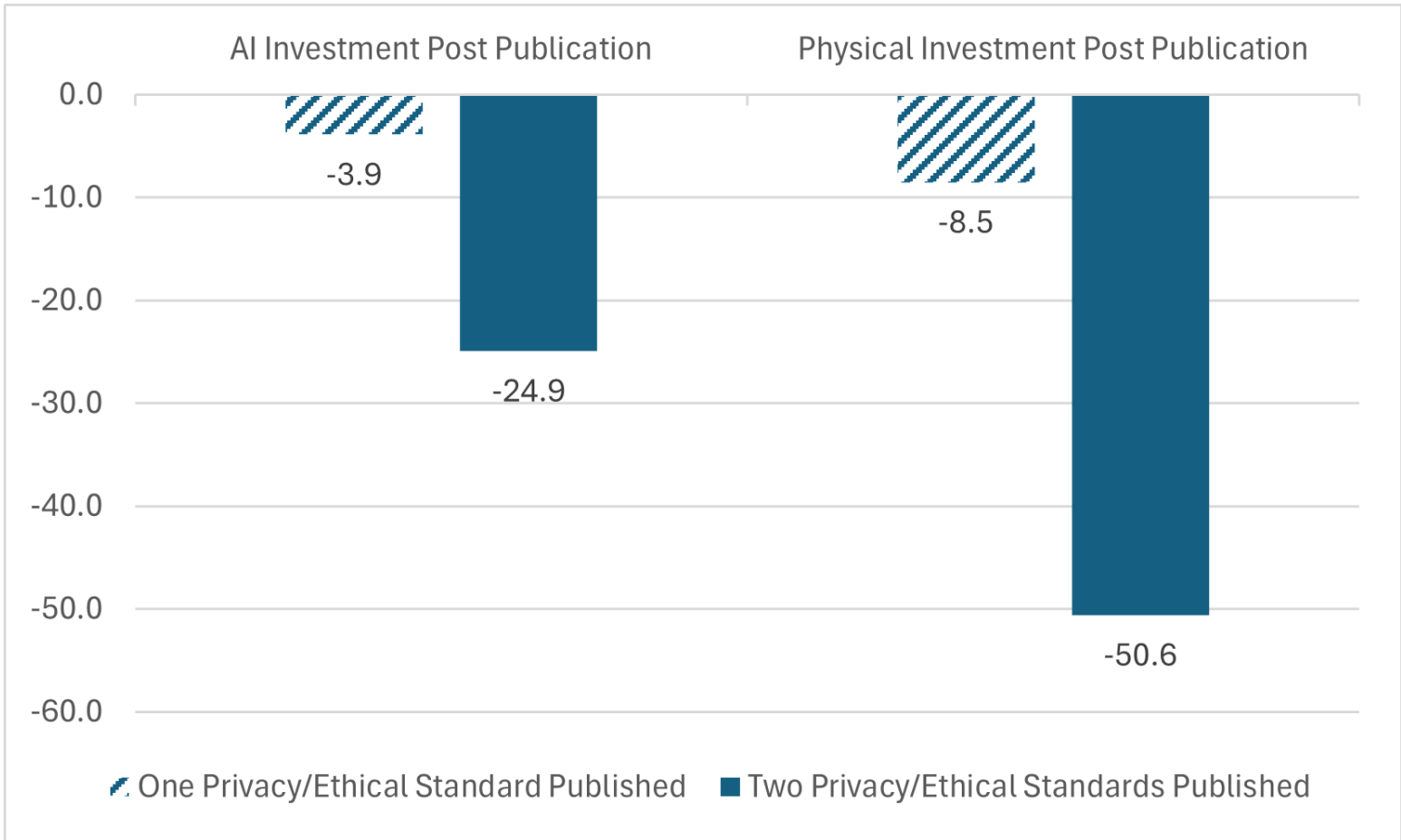
(i) If more technological standards are published, firm's post-publication AI-related investment and physical investment are higher.

(i) If more privacy/ethical standards are published, firm's post-publication AI-related investment and physical investment are lower.

Post-Publication Investment: Technological



Post-Publication Investment: Privacy/Ethical



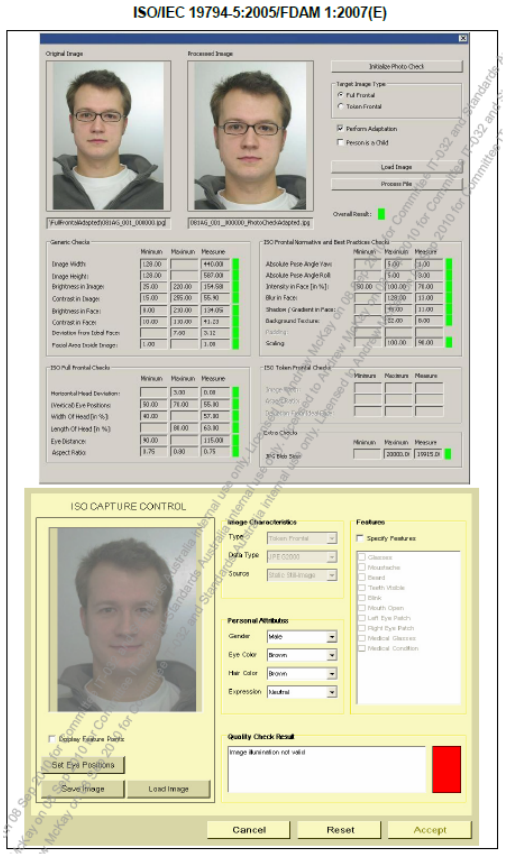
Technological Standardization

- The influence of standards on firm outcomes, especially in critical technologies like AI, is understudied.
  - Standards reduce economic uncertainty and encourage higher corporate investment.
  - However, they may stifle radical innovation and increase royalties, leaving less money for research.
- U.S. leadership in AI hinges on federal engagement in setting global standards. (EO 13859 Sections 1(b); 2(d))
  - NIST has issued a plan for AI standards development.

From Device to AI Standards: A Shift in Focus

- Unlike conventional standards, which primarily ensure compatibility, interoperability, and performance across devices, **AI standards are dedicated to guiding the successful operation of AI systems**.
  - They establish criteria for **data quality**, ensuring the accuracy, relevance, and security of the data used in AI.
  - They prescribe best practices for efficiently and reliably **training models** and **integrating them into older technologies**, such as manufacturing.
  - They aim to enable **autonomous AI-based systems** to operate in a **transparent, explainable, and fair manner**, facilitating seamless integration across various AI platforms and technologies.

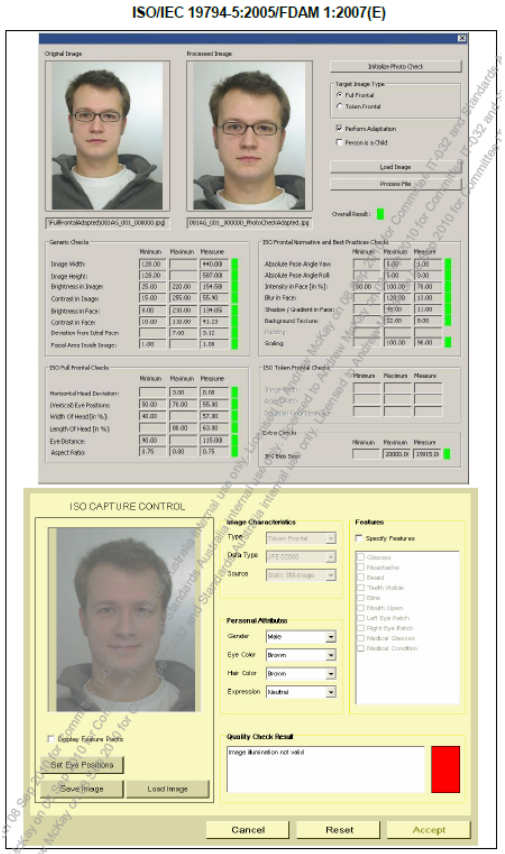
Was Your ML Model Trained Using ISO Compliant Biometric Data?



Face image quality assessment based on ISO standard 19794.

- If your ML models for self-driving vehicles aren't trained with ISO-compliant biometric data, you may need to retrain them before deployment.
- Biometric standards that align with U.S. firms' norms and comparative advantages can save both time and money.

Was Your ML Model Trained Using ISO Compliant Biometric Data?

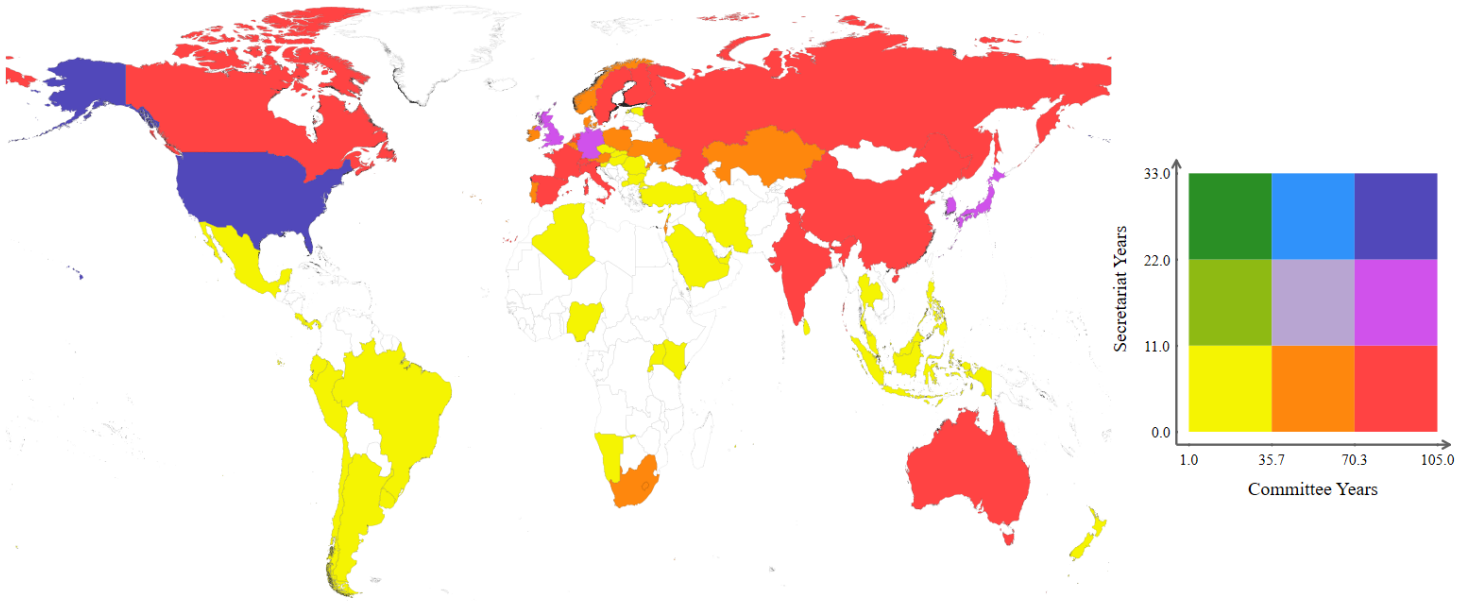


Face image quality assessment based on ISO standard 19794.

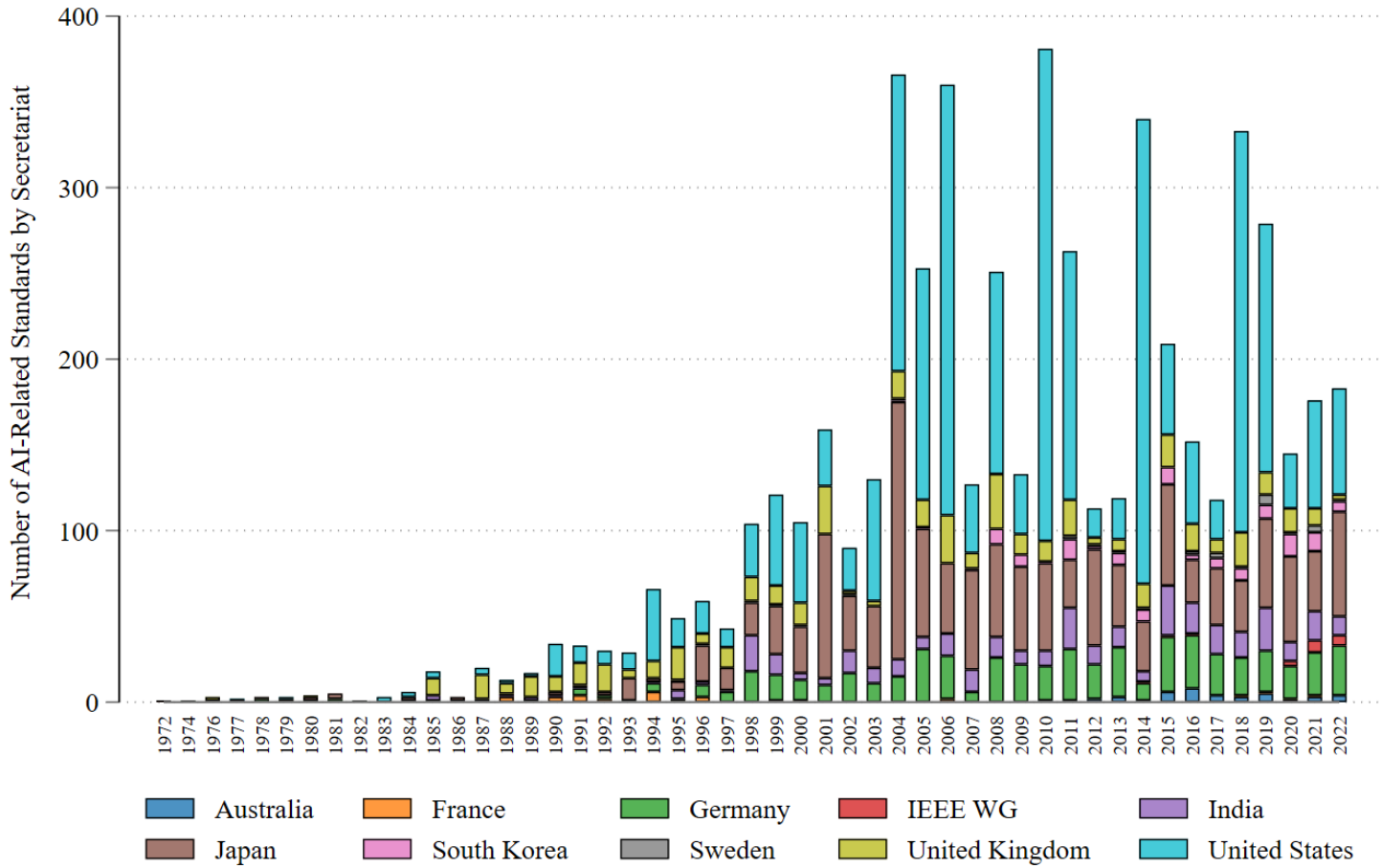
- More importantly, the global adoption of U.S. norms can generate royalties for US firms.
- Ex: Qualcomm earns around 70% of its revenue from royalties (Qualcomm vs. FTC, 2020).

Country Participation in AI Standardization

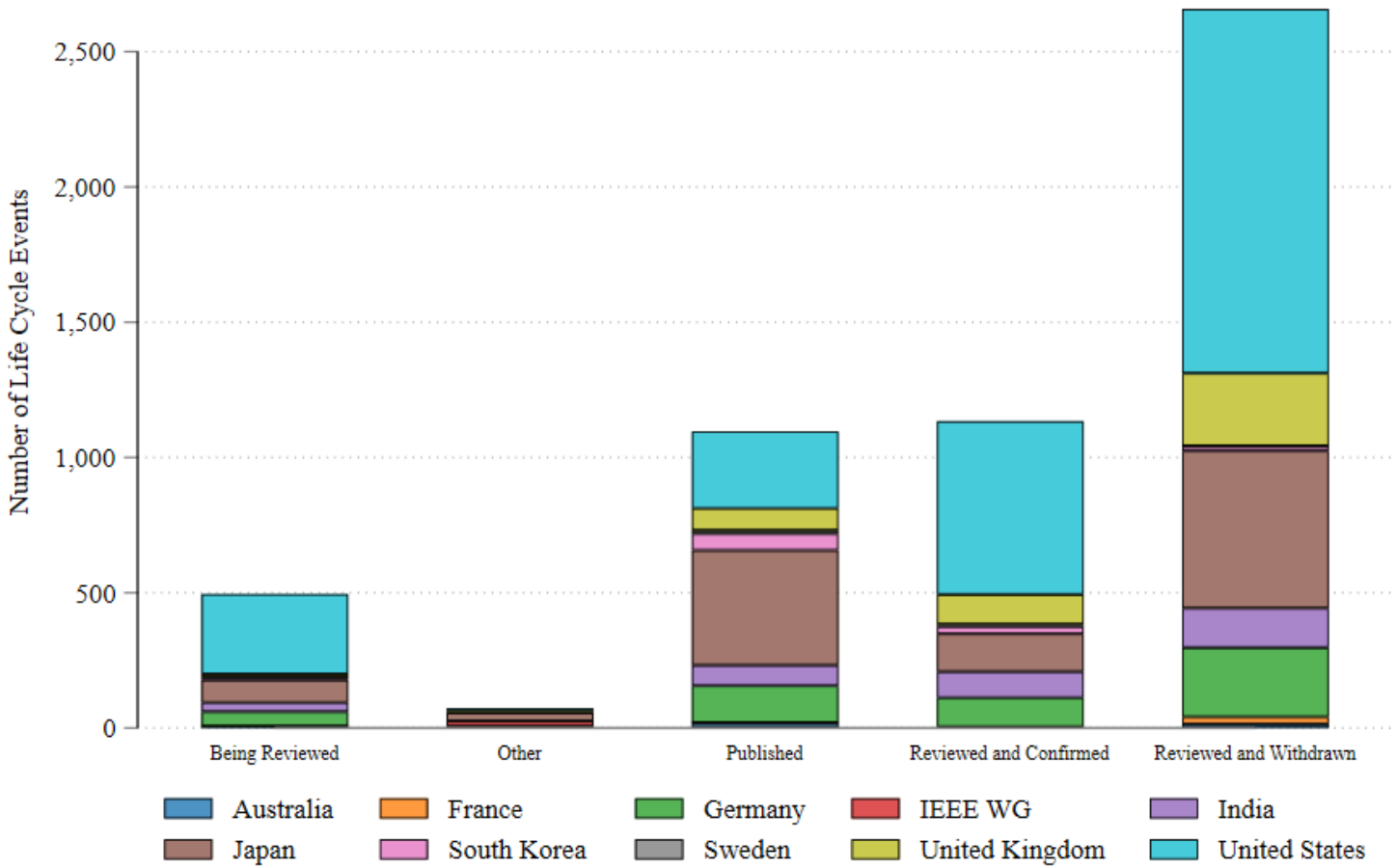
Several committee member countries vote on AI standards



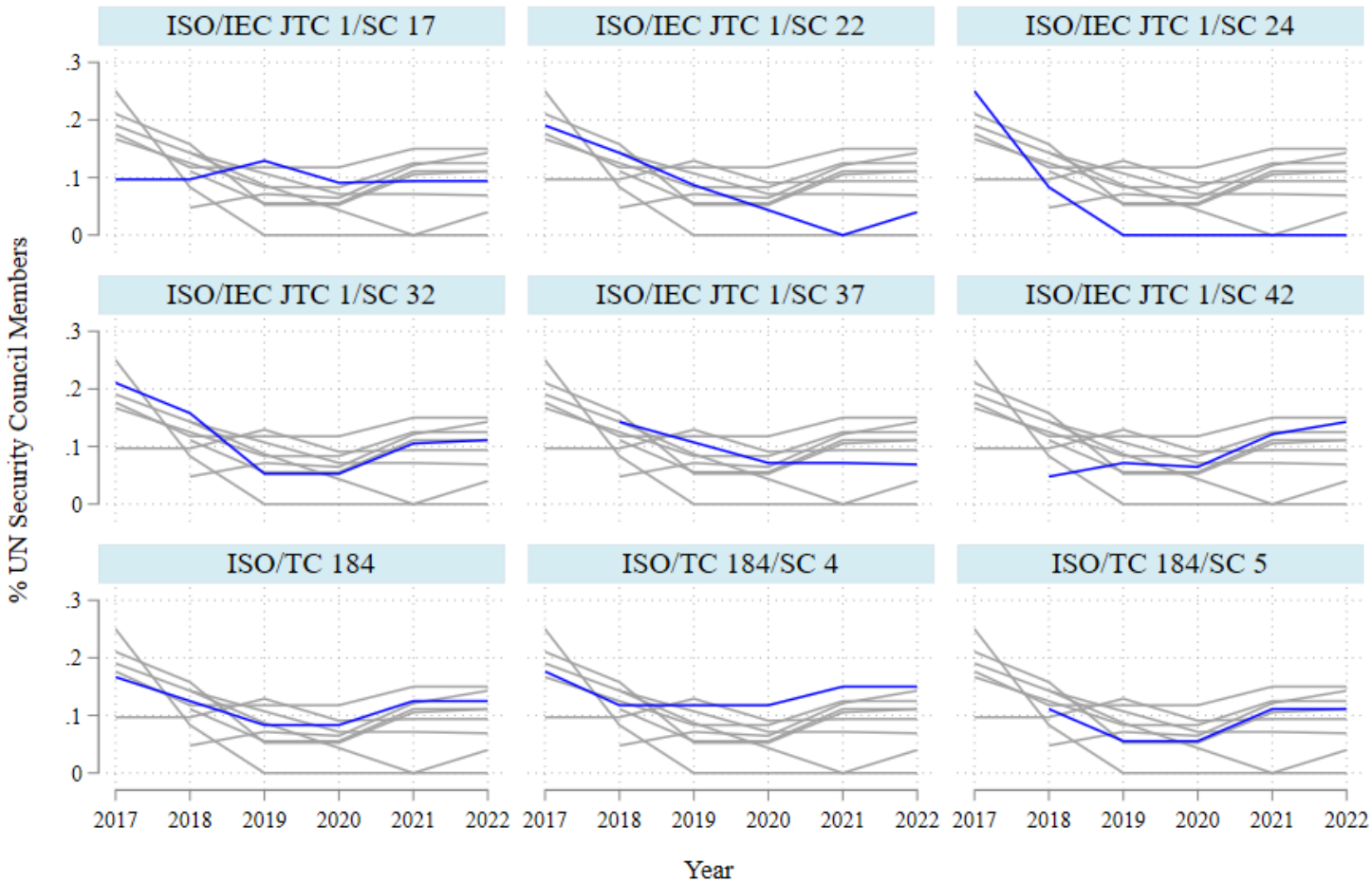
AI Standardization Activity by Secretariat



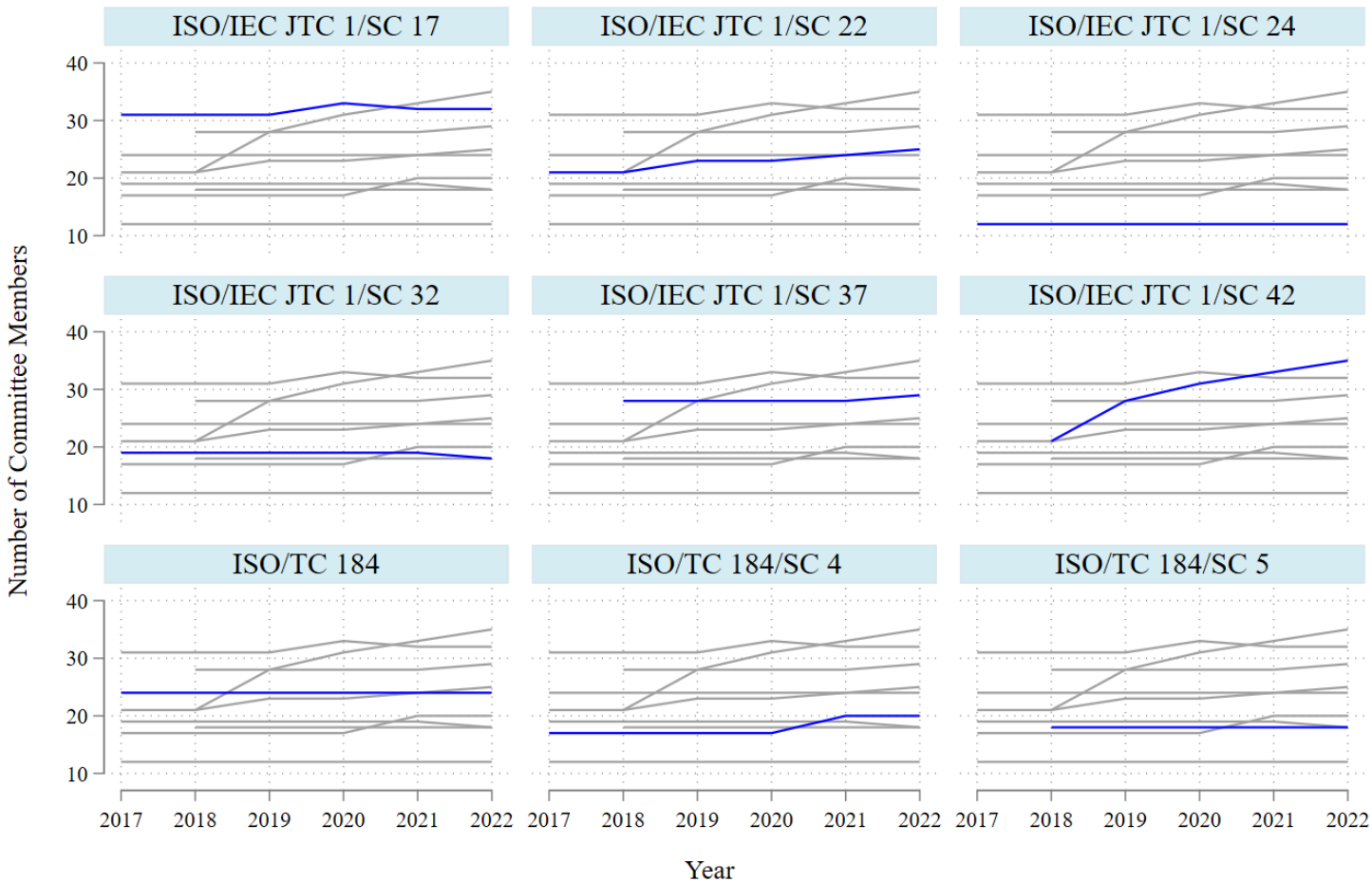
Life Cycle Events



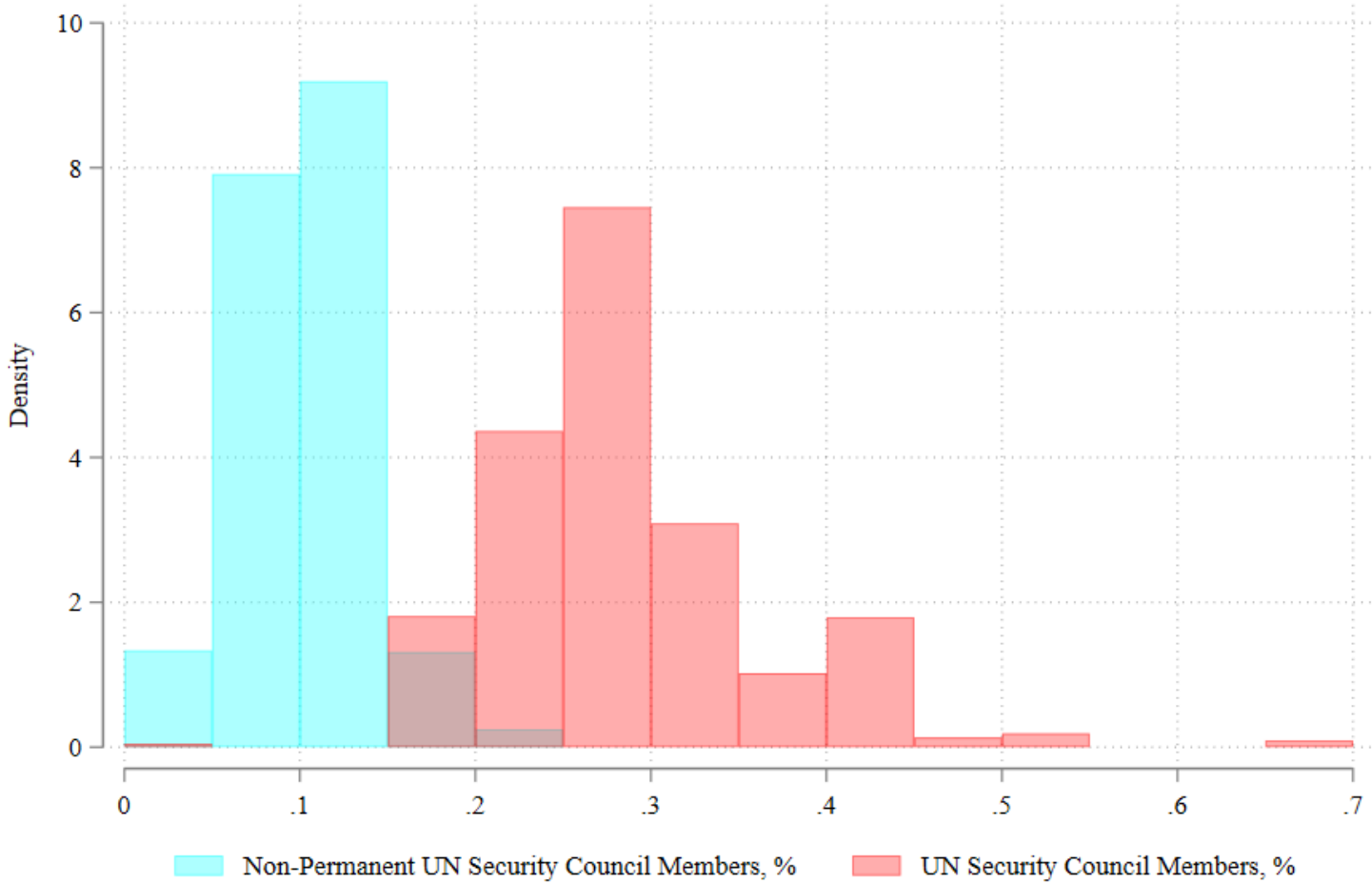
The Percentage of Rotating UNSC Members



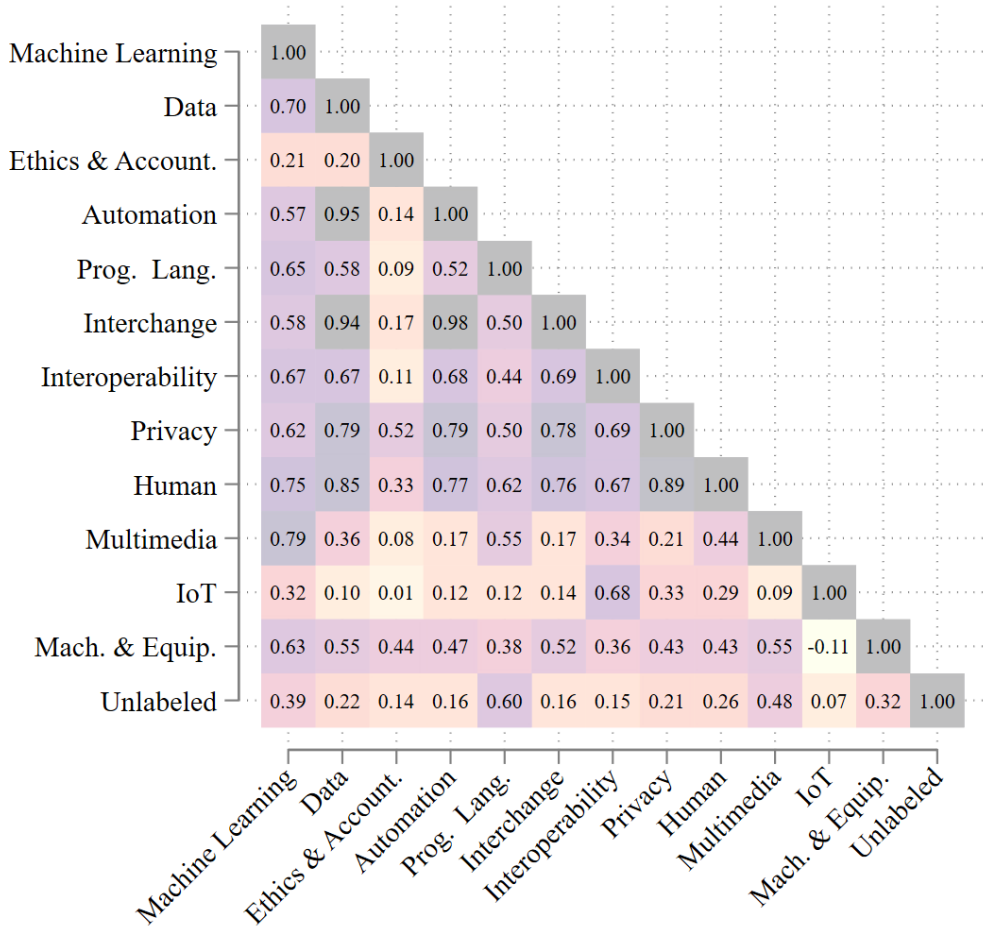
The Number of AI Committee Members



Distribution of % UNSC Membership



VCV of AI Standard Categories



Effect Dynamics on Valuation Ratios