Post-hoc Study of Climate Microtargeting on Social Media Ads with LLMs: Thematic Insights and Fairness Evaluation

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PURDUE UNIVERSITY

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Climate Change

- One of the most **urgent** challenges of the 21st century.
- Requires **broad public engagement** and **effective communication** to drive environmental action *(Moritz & Agudo, 2013; Dessler & Theater, 1995)*.

Climate Debate in Social Media

- One of the most **urgent** challenges of the 21st century.
- Requires **broad public engagement** and **effective communication** to drive environmental action *(Moritz & Agudo, 2013; Dessler & Theater, 1995).*
- Social media has become a key arena for climate communication.
- Empowers organizations, activists, and policymakers to:
  ‣ Disseminate information, Mobilize public support, Shape climate discourse *(Nosek, 2020; Hestres & Hopke, 2017; Adger et al., 2003).*
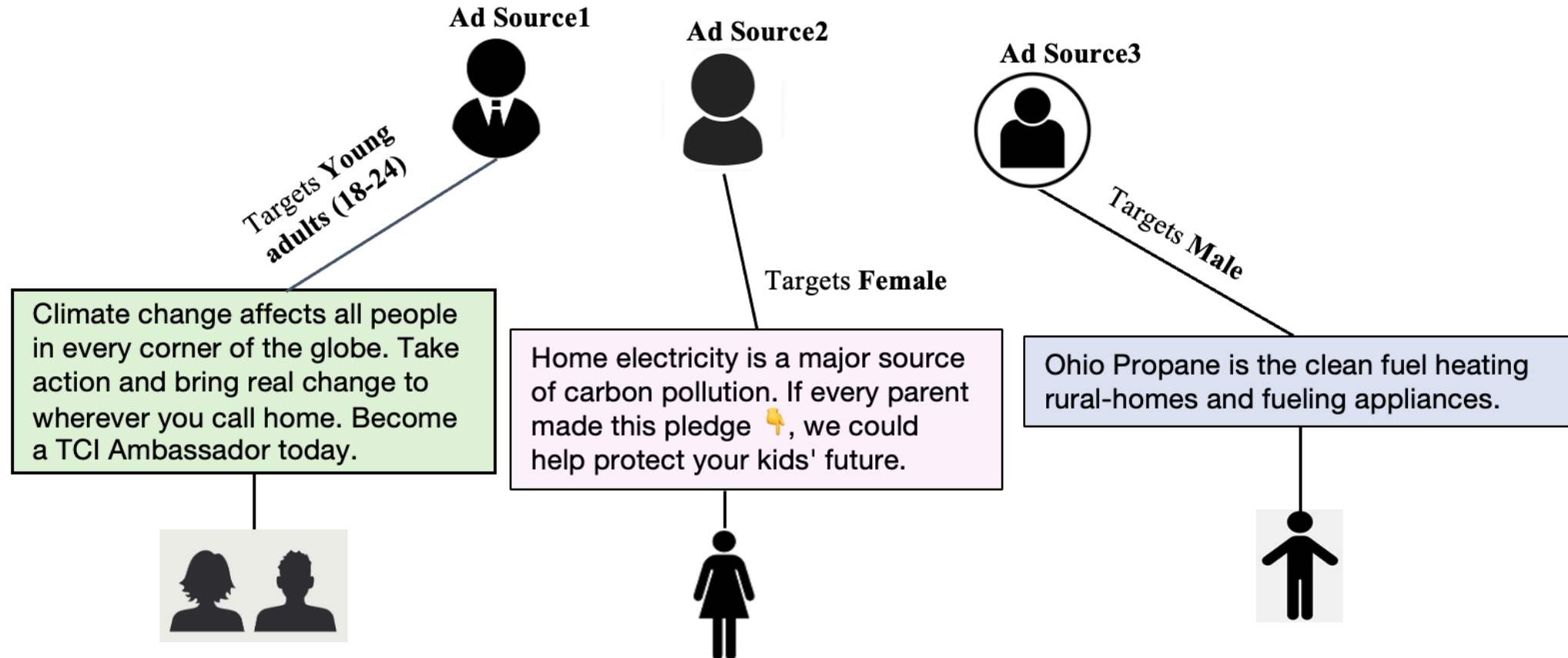
Microtargeting

Targeted Messaging Power

- Enables tailoring of messages to **specific demographics**.

- Increases message **relevance**, **engagement**, and **persuasive impact** *(Bloomfield & Tillery, 2019; Walter et al., 2018; Stoddart et al., 2016).*

- Risk reinforcing bias, exclusion, and inequity — raising critical questions about **fairness** and **transparency** in digital climate communication.

Microtargeting in Climate Debate

Ad Source1

Targets **Young adults (18-24)**

Climate change affects all people in every corner of the globe. Take action and bring real change to wherever you call home. Become a TCI Ambassador today.

Ad Source2

Targets **Female**

Home electricity is a major source of carbon pollution. If every parent made this pledge 👇, we could help protect your kids' future.

Ad Source3

Targets **Male**

Ohio Propane is the clean fuel heating rural-homes and fueling appliances.
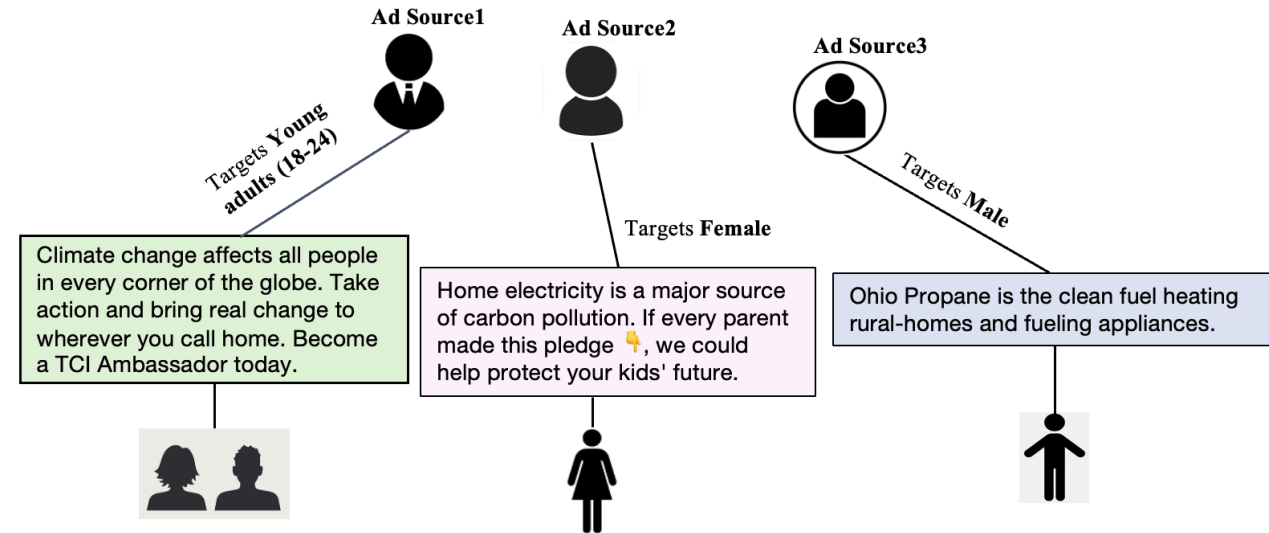
Microtargeting in Climate Debate

- **Problem**: Limited understanding of *how* microtargeting strategies are crafted and whether they're **fair or biased**.

- **Goal**: Leverage LLMs to analyze microtargeting and evaluate **demographic targeting** and **fairness**.

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Ad Source3 — Targets **Male**

Ohio Propane is the clean fuel heating rural-homes and fueling appliances.

Research Questions (RQ)

- **RQ1:** Can LLMs **identify** targeted demographics and **explain** their reasoning?

- **RQ2:** What are the recurring themes and aspects of **explanations** provided by LLMs?

- **RQ3:** How **fair** are LLM predictions across demographic groups?

Dataset: Climate Campaigns Case Study

- Source
  - Based on Islam et al. (2023b) and Islam & Goldwasser (2024a)
  - **Corpus:** 21,372 English climate-related Meta ads (U.S.)
  - **Time span:** Jan 2021 – Jan 2022
- Ad Attributes:
  - Ad ID, description, body, funding entity, spend, impressions
  - Impression breakdowns by: **Gender, Age, Location:** U.S. state level
- **Demographics Indicators:**
  - **Gender**:
    - *Male*,
    - *Female*
  - **Age groups**:
    - *Young adults* 18-24,
    - *Early working* 25-44,
    - *Late working* 45-64,
    - *Seniors* 65+

Dataset: Climate Campaigns Case Study

- Targeting Definition
  - Meta API does **not** provide explicit targeting
  - Targeting **inferred** from *exclusive impression* distributions
    - Ads viewed **only by one gender** or **only by one age group**
    - Ads overlapping multiple categories **excluded**

- Filtered Dataset

Category	Targeting Basis	# Ads
Gender-targeted	Male-only / Female-only	106
Age-targeted	Exclusive to one age group	121
Total (after filtering)	—	**227**

Experimental Setup

- **Task**: **Identify** the targeted demographic in a text and provide an **explanation**.

- Pipeline steps
  - **Gender prediction with explanation**: Given a text, predict the targeted gender and justify the choice.

  - **Age group prediction with explanation**: Given a text, predict the targeted age group and justify the choice.

Experimental Setup

- **Tools used**: OpenAI's latest LLM (**o1-preview**)

- **Baseline comparisons**: $LR_{TF\text{-}IDF}$, BERT, Llama 3, Mistral Large 2

- **Fairness metrics**:
  - Demographic Parity,
  - Equal Opportunity,
  - Predictive Equality.

Results

- Prediction Accuracy Across Demographic Groups

Prediction Accuracy Across Demographic Groups
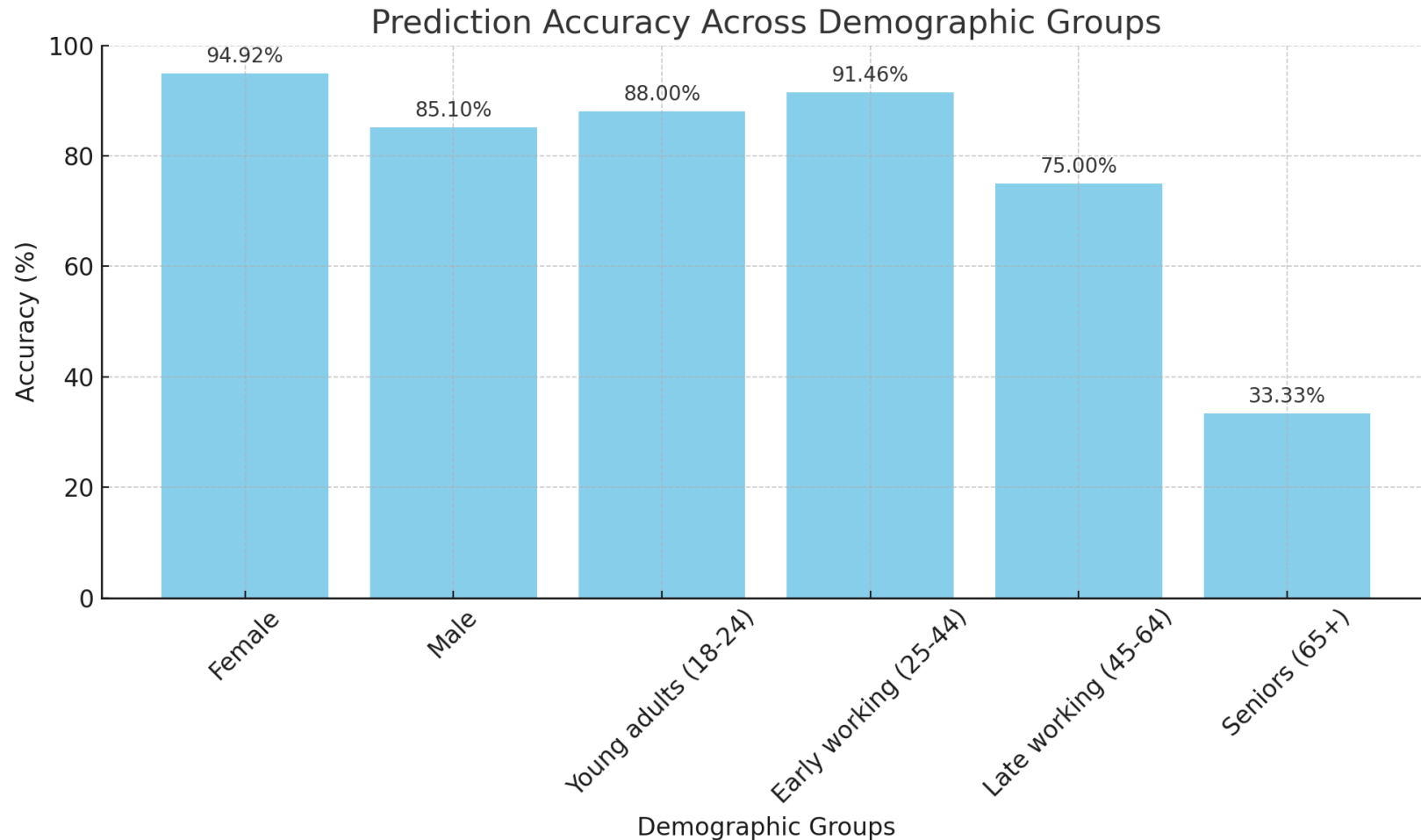
Results

Model	Demo.	Acc. (%)	F1 (%)
LR_tf-idf	gender	69.00	65.00
LR_tf-idf	age	73.00	31.00
BERT	gender	72.00	70.00
BERT	age	70.00	26.00
Llama 3	gender	80.19	79.67
Llama 3	age	58.68	36.84
Mistral Large 2	gender	82.08	82.07
Mistral Large 2	age	74.38	48.68
o1-preview	**gender**	**90.57**	**90.35**
o1-preview	**age**	**85.95**	**71.00**

Table 1: Baseline Comparisons.

Results

Gender	p-value	Conclusion
Male	5.35×10^{-7}	Reject H_0
Female	5.95×10^{-14}	Reject H_0

Table 2: Significance tests by subgroup (gender).

Age Group	p-value	Conclusion
Senior	4.66×10^{-1}	Fail Reject H_0
EarlyWorking	1.04×10^{-35}	Reject H_0
Young	5.76×10^{-11}	Reject H_0
Late Working	4.23×10^{-3}	Reject H_0

Table 3: Significance tests by subgroup (age).

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Thematic Insights (Explanations from LLM)

perceived interests and roles in technology, finance, property, traditional male activities, and political or economic discourse
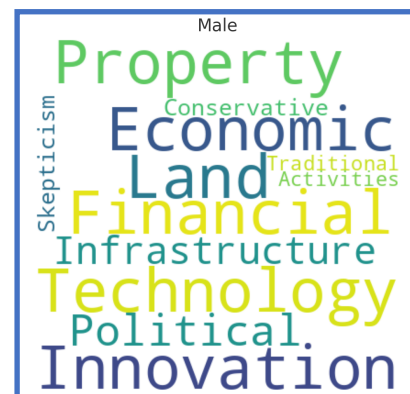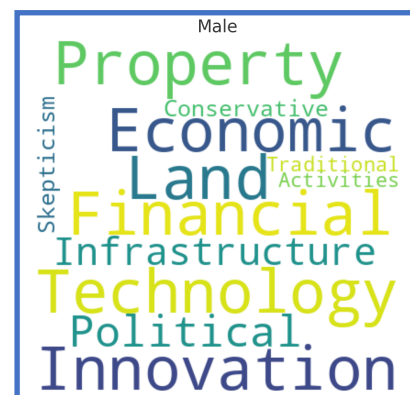
Thematic Insights (Explanations from LLM)

Roles as Caregivers, Environmental Advocates, and Socially Conscious Individuals

perceived interests and roles in technology, finance, property, traditional male activities, and political or economic discourse

Male
Property
Conservative
Economic
Land Traditional Activities
Skepticism
Financial
Infrastructure
Technology
Political
Innovation

Female
Leadership
Community
Health
Environmental
Welfare
Advocacy
Social
Empathy Safety
Empowerment
Caregiving
Emotional

Young Adults
Activism
Bold
Climate
Passion
Training
Leadership
Change Advocacy
Action
Environmental
Immediate

Early Working
Parental
Political
Financial
Innovation
Stability
Career
Proactive
Technology
Responsible
Social

Late Working
Policy
Financial
Voter
Stability
Economic
Homeownership
Responsibility
Engagement

Seniors
Health
Safety
Vulnerability
Wellness

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Thematic Insights (Explanations from LLM)

Male
Property
Conservative
Skepticism
Economic
Land Traditional Activities
Financial
Infrastructure
Technology
Political
Innovation

Female
Leadership
Community
Health
Environmental
Welfare
Social Advocacy
Empathy Safety
Empowerment
Caregiving
Emotional

Young Adults
Activism
Training
Bold
Climate Passion
Leadership
Change Advocacy
Action
Environmental
Immediate

Activism and Environmental Consciousness

Early Working
Parental
Financial
Political Innovation
Stability
Career
Proactive
Technology
Responsible
Social

Late Working
Policy
Voter Financial
Stability
Economic
Homeownership
Responsibility
Engagement

Seniors
Health
Safety
Vulnerability
Wellness

Thematic Insights (Explanations from LLM)

Male

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Conservative
Economic
Land Traditional Activities
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Activism and Environmental Consciousness

Early Working

Parental
Financial
Political Innovation
Stability
Career
Proactive
Technology
Responsible
Social

Proactive and Responsible Mindset

Late Working

Policy
Voter Financial
Stability
Economic
Homeownership
Responsibility
Engagement

Seniors

Health
Safety
Vulnerability
Wellness

Thematic Insights (Explanations from LLM)

Male: Property, Conservative, Skepticism, Economic, Land, Traditional Activities, Financial, Infrastructure, Technology, Political, Innovation

Female: Leadership, Community, Health, Environmental, Welfare, Advocacy, Social, Empathy, Safety, Empowerment, Caregiving, Emotional

Young Adults: Activism, Bold, Passion, Climate, Training, Leadership, Change, Advocacy, Action, Environmental, Immediate

Activism and Environmental Consciousness

Early Working: Parental, Financial, Innovation, Political, Stability, Career, Proactive, Technology, Responsible, Social

Late Working: Policy, Financial, Voter, Stability, Economic, Homeownership, Responsibility, Engagement

Seniors: Health, Safety, Vulnerability, Wellness

Proactive and Responsible Mindset

Responsibilities and Concerns

Thematic Insights (Explanations from LLM)

Male
Property
Conservative
Economic
Land Traditional Activities
Skepticism
Financial
Infrastructure
Technology
Political
Innovation

Female
Leadership
Community
Health
Environmental
Welfare
Advocacy
Social Empathy Safety
Empowerment
Caregiving
Emotional

Young Adults
Activism
Bold
Passion
Climate Leadership Training
Change Advocacy
Action
Environmental
Immediate

Activism and Environmental Consciousness

Early Working
Parental
Financial
Innovation
Political Stability
Career
Proactive
Technology
Responsible
Social

Late Working
Policy
Financial
Voter Stability
Economic
Homeownership
Responsibility
Engagement

Seniors
Health
Safety
Vulnerability
Wellness

Health and Safety Concerns

Proactive and Responsible Mindset

Responsibilities and Concerns

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Fairness Evaluation

Minor bias **favoring females**.
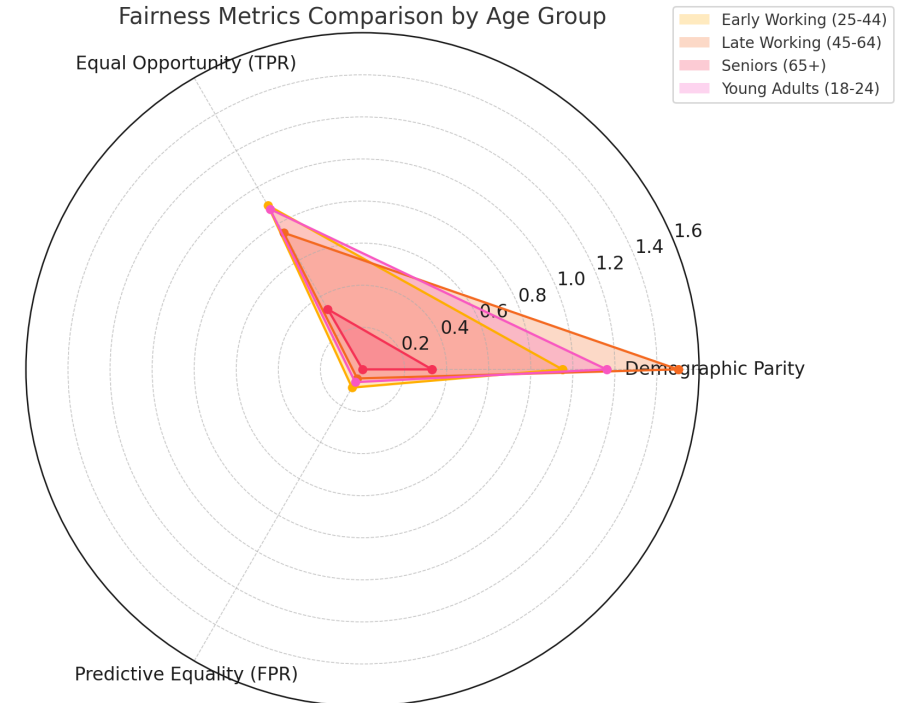
- Minor bias **favoring late working age group**.
- Significant bias **against seniors**.

Key Takeaways

LLMs as Auditors

- LLMs can act as **independent, third-party auditors** of **microtargeted climate ads**.

- They can **identify intended audiences**, **explain reasoning**, and **reveal fairness issues** that are otherwise opaque.

Strong Predictive Capability

- **Gender prediction:** Highly accurate (Female $= 94.92\%$, Male $= 85.10\%$).

- **Age prediction:** More variable — highlights complexity of age-based targeting.

Key Takeaways

Explainable Insights

- LLM-generated **explanations** support creation of a **reusable taxonomy** of thematic appeals used in ads.

- These explanations make demographic targeting **interpretable and actionable** for researchers and practitioners.

Fairness & Equity

- **Fairness analysis** reveals **disparities** across gender and age groups.

- Demonstrates the **need for inclusive, equitable ad-targeting** and **bias-aware AI evaluation frameworks**.

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THANK YOU ☺

Slide: https://tunazislam.github.io/files/PosthocClimateLLM.pdf

Questions?

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