URP 6931. Introduction to Urban Analytics

Lecture 12: Analytical fairness

Instructor: Shenhao Wang
Assistant Professor, Director of Urban AI Lab
Department of Urban and Regional Planning
University of Florida

Disclaimers

1. Today's lecture is about exploratory views, so I am open to discussions and your feedbacks are important.
2. I did not grow up in the US, so I would like to learn socially acceptable methods to discuss fairness.

Outline

1. Fairness definitions in analytics
2. Analytical fairness in urban applications
3. Computational fairness (ML) & general comments
4. Lab session (two exercises)
5. Guest lecture (3:45-4:30)

Part 1. Fairness definitions in analytics

Equity, equality, and Rawlsian fairness

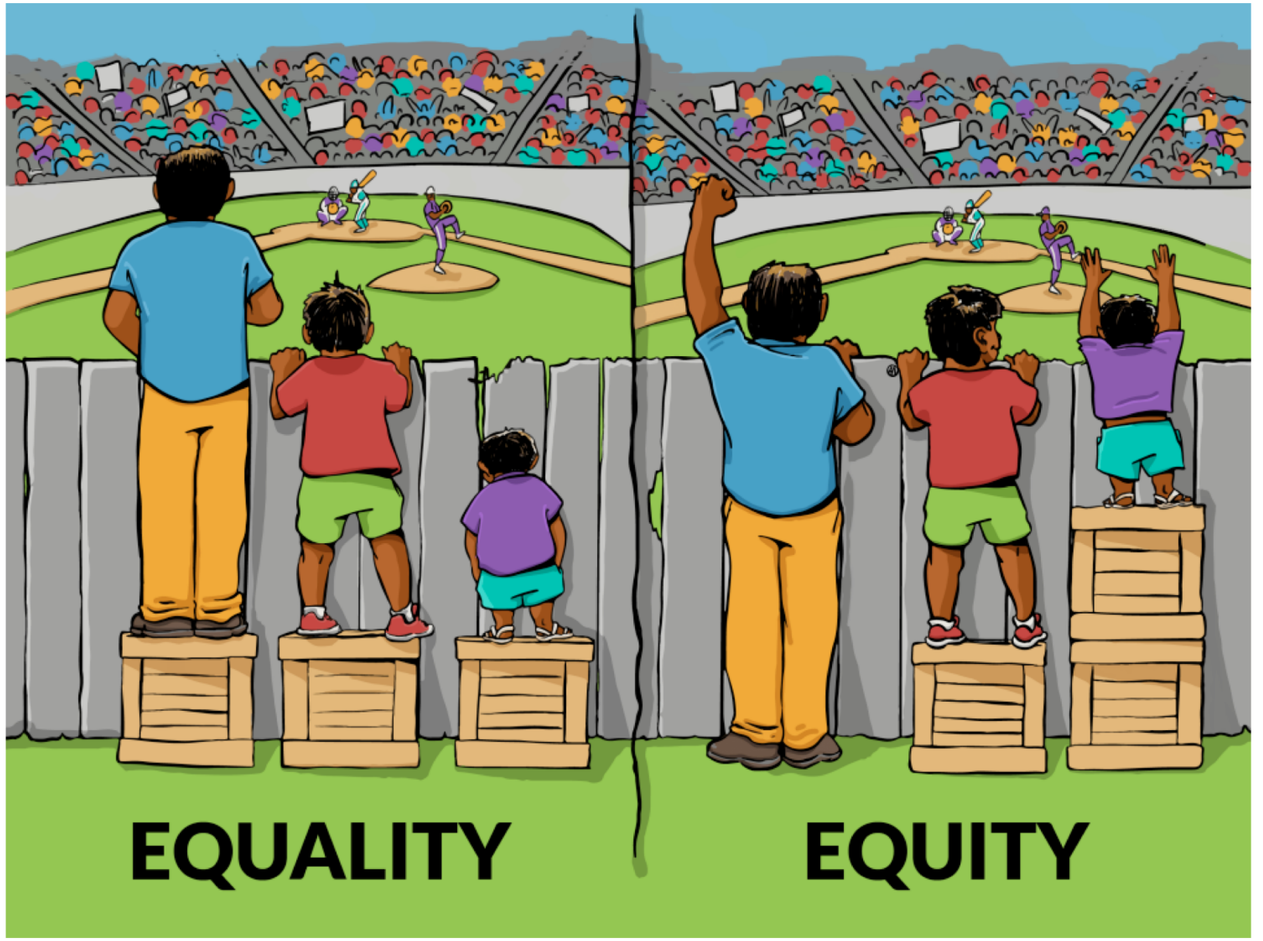
Equality	Equality is the state of being equal, especially in status, rights and opportunities. Equality means each individual or group of people is given the same resources and opportunities, regardless of their circumstances. Cite: https://unitedwaynca.org/blog/what-is-equality/
Equity	Whereas equality means providing the same to all, equity means recognizing that we do not all start from the same place and must acknowledge and make adjustments to imbalances. Cite: https://www.naceweb.org/about-us/equity-definition/
Rawlsian fairness	Each person has the same and indefeasible [permanent] claim to a fully adequate scheme of equal basic liberties [rights], which scheme is compatible with the same scheme of liberties for all. Cite: https://www.crf-usa.org/bill-of-rights-in-action/bria-23-3-c-justice-as-fairness-john-rawls-and-his-theory-of-justice

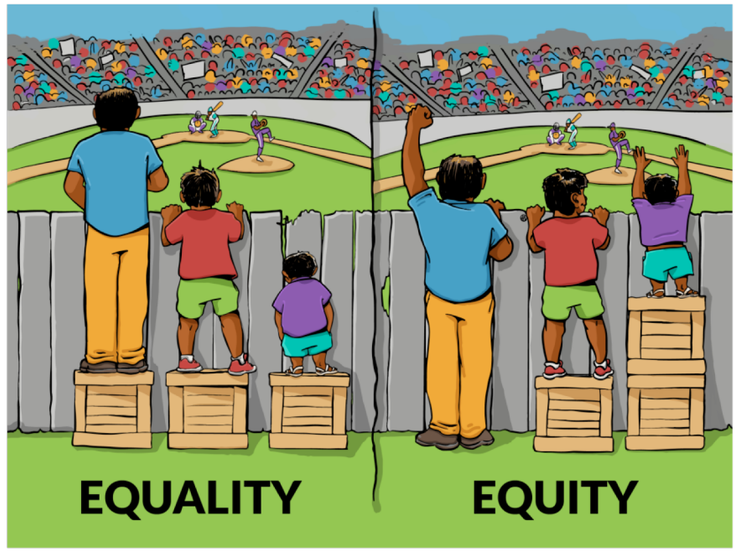
Philosophical discussions could be confusing, but they can be reduced to simple math definitions.

Note

- Shenhao's learning trajectory.

Equality and equity

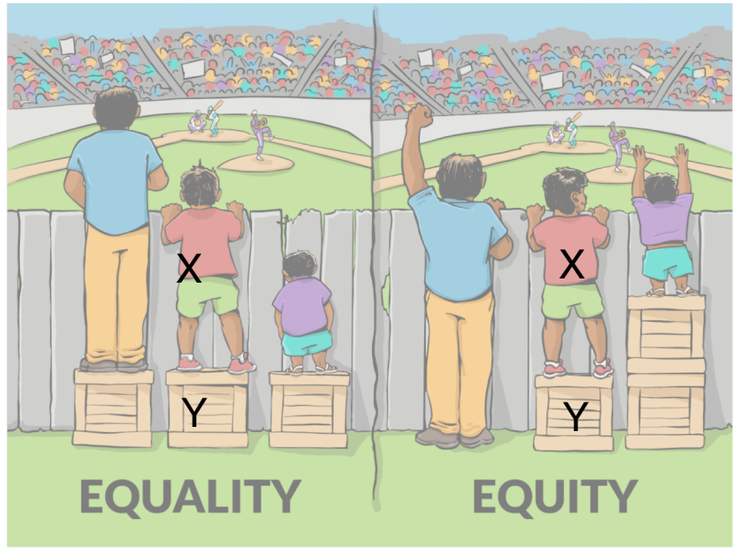




Equality and Equity

Question

Could you see regression lines from the two pictures?



Equality and Equity

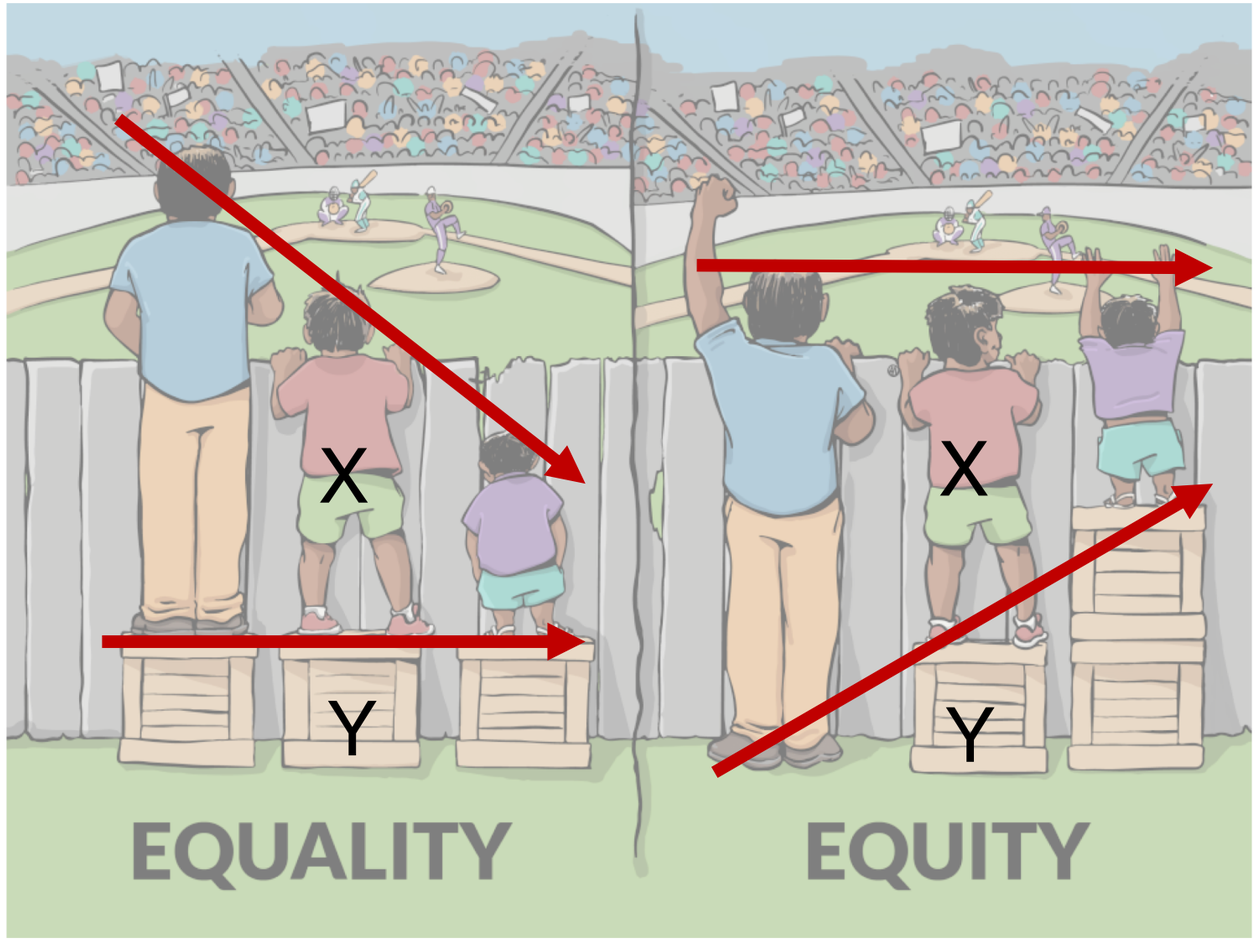
Question

Could you see regression lines from the two pictures?

X&Y

- Y: resources.
- X: socially sensitive group, including advantaged and disadvantaged subgroups. (measured by discrete or continuous variables)

Equality and equity

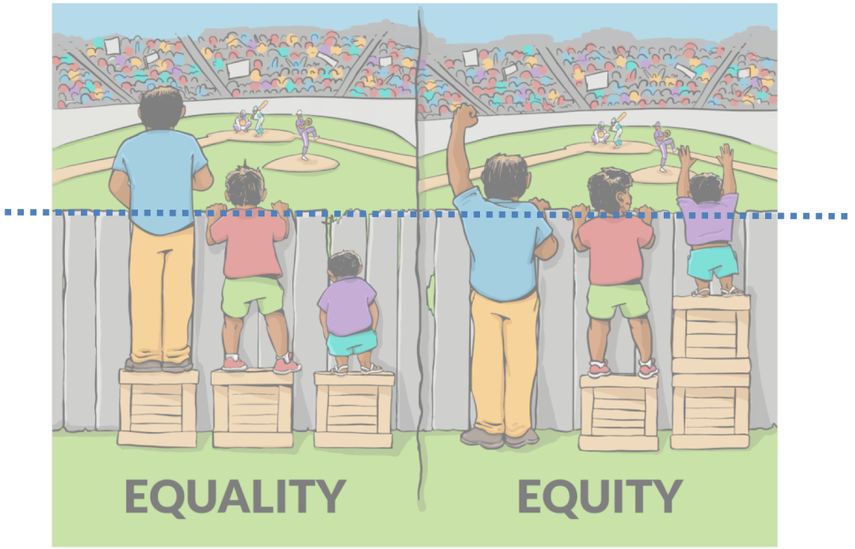


Y: resources
X: socially sensitive groups

Equality: Y does not vary with X.
Equity: Y increases as X increases.

Question: How are equality and equity corresponding to $\hat{\beta}_1$?
Equality: $\hat{\beta}_1 = 0$
Equity: $\hat{\beta}_1 <> 0$

Example. Y: food access. X: age.
Equality: $\hat{\beta}_1 = 0$
Equity: $\hat{\beta}_1 > 0$



Where is the basic right?

Rawls: even the most disadvantaged group has a basic right.

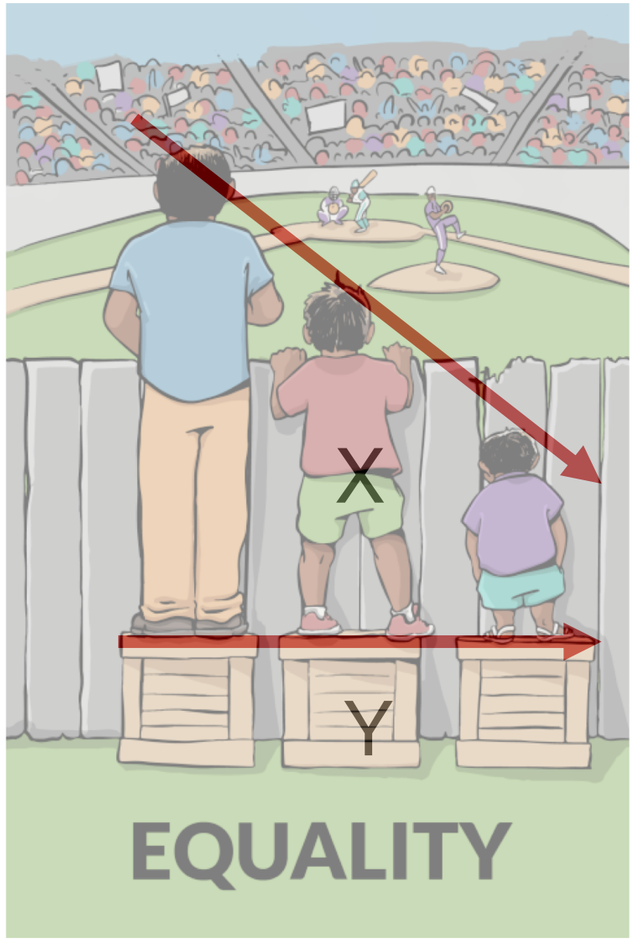
Y: resources

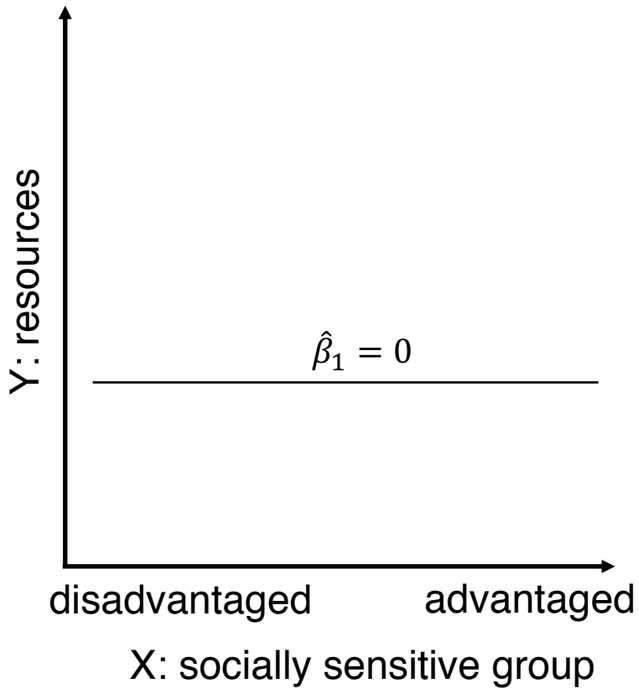
X: socially sensitive groups (larger X indicates more advantaged group)

Interpretation of $\hat{\beta}_0$ actually aligns with the basic right intuition.

Basic right: $\widehat{\boldsymbol{\beta}}_{\mathbf{0}} > \boldsymbol{threshold}$

Analytical fairness in a univariate regression: equality rule





Define fairness

- Equality: Y does not vary with X. ($\hat{\beta}_1 = 0$)

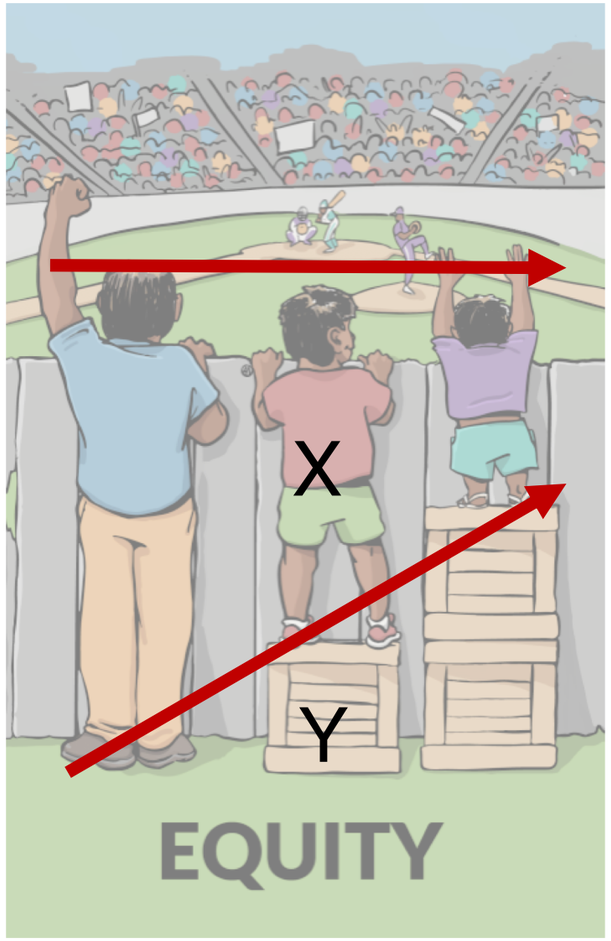
Identify the context & run the regression

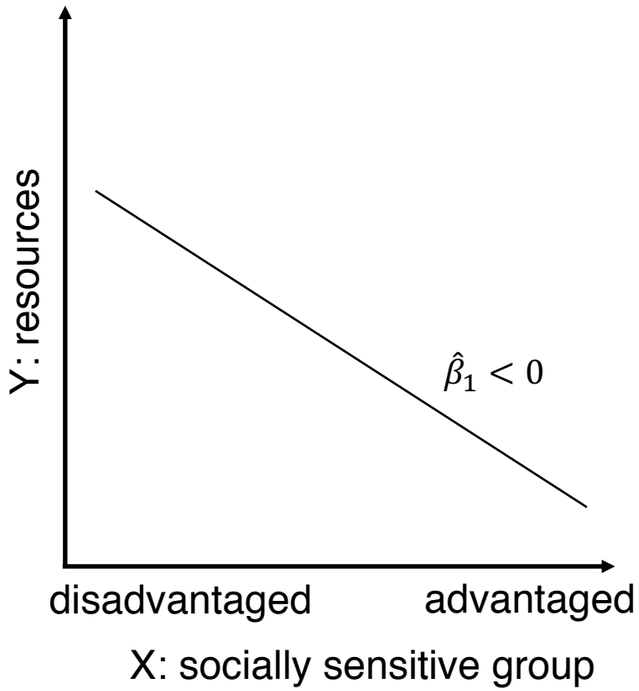
- Y: resources
- X: socially sensitive groups
- Recovering $\hat{\beta}_1$

Make normative evaluation

- Fair vs. Unfair

Analytical fairness in a univariate regression: equity rule





Define fairness

- Equity: Y varies with X. ($\hat{\beta}_1 < 0$)

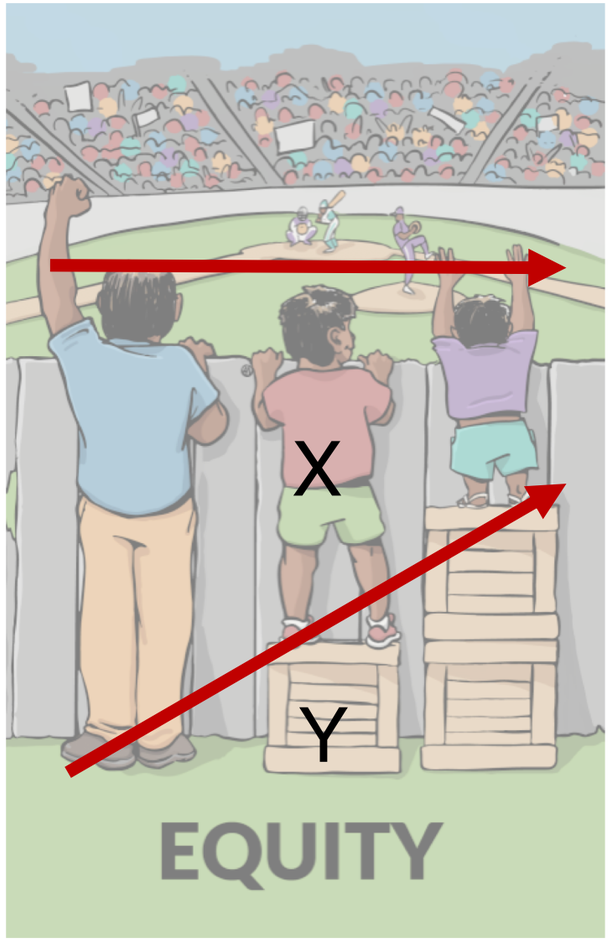
Identify the context & run the regression

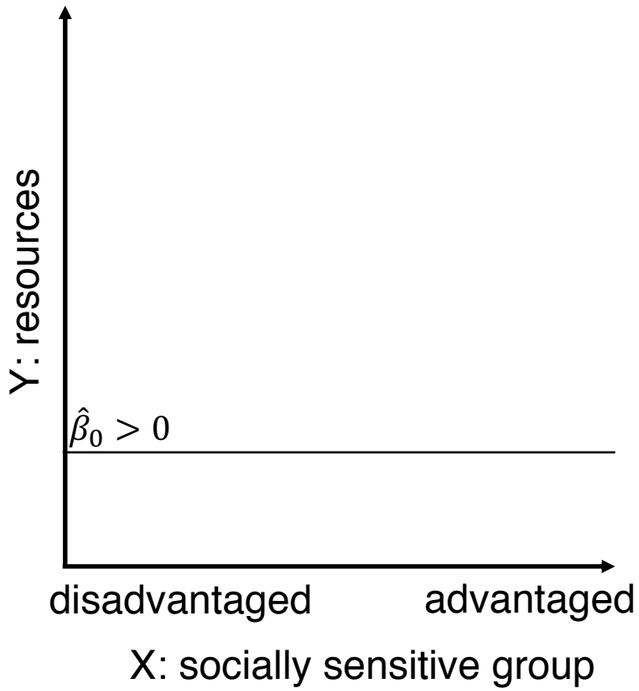
- Y: resources
- X: socially sensitive groups
- Recovering $\hat{\beta}_1$

Make normative evaluation

- Fair vs. Unfair

Analytical fairness in a univariate regression: Rawlsian rule





Define fairness

- Rawlsian: Weakest group has positive resource. ($\hat{\beta}_0 > 0$)

Identify the context & run the regression

- Y: resources
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Make normative evaluation

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Equality

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$$\hat{\beta}_1 = 0$$

Equity

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$$\hat{\beta}_1 <> 0$$

Rawlsian justice

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$$\hat{\beta}_0 > t$$

Two Questions

Q1. How to deal with the conflicting fairness rules?

Q2. How about the multivariate regressions?

Part 2. Analytical fairness in urban applications

Wide urban applications with analytical fairness

Examples about X and Y

1. Socially sensitive group: disadvantaged vs. advantaged social subgroups.
   - Examples: income (poor vs. rich), age (senior vs. young), race (majority vs. minority), gender (female vs. male), household (large vs. small sizes), etc.
2. Resources.
   - Examples: food, transportation, housing, economic growth, new technology, etc.

Any combination between 1&2 can leads to a valid urban application about fairness.

Example 1

1. Sensitive group: income; disadvantaged vs. advantaged social subgroups: low vs. high-income groups
2. Resources: food accessibility.
3. Process: (1) define fairness, (2) run regression, and (3) make fairness evaluation

Example 2

1. Sensitive group: age; disadvantaged vs. advantaged social subgroups: senior vs. other groups
2. Resources: housing
3. Process: (1) define fairness, (2) run regression, and (3) make fairness evaluation.

Process of evaluating fairness

This standard structure exists in ANY fairness evaluation.

This step is the new contents (lec12)

1. Major premise

Fairness is defined as the equity rule (a.k.a. $\hat{\beta}_1 <> 0$)

This step is the old contents (lec03-05)

2. Minor premise

Choose Y = food access and X = age.

Run the regression and recover the $\hat{\beta}$ values.

3. Conclusion

Compare the fairness definition from step 1 and the signal from step 2. Then conclude the food access in Florida is fair/unfair to the seniors.

Process of criticizing fairness evaluation

Q: How do you define fairness?

1. Major premise

Fairness is defined as the equity, equity, Rawlsian rule, or anything else?

Q: How do you analyze your data?

2. Minor premise

- How to choose the appropriate X & Y.
- A1: omitting variable bias.
- A2: function misspecification problem.
- Others: sampling, etc.

3. Conclusion

Compare the fairness definition from step 1 and the signal from step 2. Then previous conclusions will change.

Part 3. Computational fairness (ML)

From statistics to ML: computational fairness

1. This term was created in the ML field around 5~10 years ago.
2. ML focuses on the prediction accuracy, so the key is to treat prediction accuracy as resource.
3. Examples & consequences of unequal prediction accuracy
    - Predicting economic development for rich vs. poor areas.
    - Predicting transit demand for senior vs. young people.
    - Predicting the adoption of new technology for racial minority vs. majority groups.
4. Unequal prediction accuracy leads to further unequal treatment.
    - Fewer infrastructure investment in poor areas
    - Less transit development for the senior areas.
    - Less new technology delivery in racial minority groups.
5. ML approaches could introduce regularization to rebalance prediction accuracy across disadvantaged vs. advantaged social subgroups to achieve computational fairness.

Various concepts in computational fairness

Definition of fairness in ML

- Accuracy parity. (similar to $\hat{\beta}_1 = 0$)
- Threshold parity. (similar to $\hat{\beta}_0 = 0$)
- Positive discrimination. (similar to $\hat{\beta}_1 <> 0$)
- Others: equal opportunities, etc.

Example: accuracy parity

$$P(\hat{y} = y \,|x = 1) = P(\hat{y} = y \,|x = 0)$$

Sometimes it is hard to obtain the exact equality form, so we examine:

$$\lambda_1 < \frac{P(\hat{y} = y \,|x = 1)}{P(\hat{y} = y \,|x = 0)} < \lambda_2$$

What analytical fairness (Stats & ML) can and cannot do

Can do:

1. Major premise - Provide exact definitions for fairness
- Rawlsian fairness
- Equity
- Equality
- etc.

2. Minor premise - Provide rigorous analytics about facts/evidence
- Statistical regressions
- Network analysis
- ML

3. Concluding fairness evaluation

Cannot do:

Choose the ultimate fairness rule.
- Equity and equality rules inherently conflict.
- Rawlsian fairness and equity may not be satisfied simultaneously
- Rawlsian fairness and equality may not be satisfied simultaneously
- etc.

Comments

1. However, traditional planning practices cannot identify the ultimate fairness rule either.
2. This fundamental conflict among fairness rules reveals the power of analytical fairness, not weakness.
3. The single ultimate fairness rule is context-dependent, and heavily depend on social preferences.