Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Simpson's Paradox in COVID-19 Fatality Rates

Causal Networks: Learning and Inference

Julius von Kügelgen[1, 2], Luigi Gresele[1], Bernhard Schölkopf[1]

[1]Max Planck Institute for Intelligent Systems, Tübingen, Germany

[2]Department of Engineering, University of Cambridge, United Kingdom

December 3, 2021

Outline

1. Introduction
   - General Overview
   - Simpson's Paradox
   - Inference
   - Model
   - TCE
   - Mediation
2. Mediation Analysis
   - CDE
   - NDE
   - NIE
   - Interactions
   - Case Study
   - Discussions
   - Considerations

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Section 1

Introduction

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

A General Overview

- After the outbreak in Wuhan in December 2019, SARS-CoV-2 pandemic started being reported across multiple Countries, all over the world. One of the most cited indicators used to describe and compare the impact of the pandemic in different Countries was **Case Fatality Rate (CFR)**: *the proportion of deaths between SARS-CoV-2 infection confirmed cases.*

- It is important to notice that this measure is strongly influenced by **the definition of *"confirmed cases"***. **Confounding** introduced by Country - specific testing policies can strongly impact on the interpretation of the results. This was the case when **comparing first-wave CFR between China and Italy!**

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

A General Overview

- After the outbreak in Wuhan in December 2019, SARS-CoV-2 pandemic started being reported across multiple Countries, all over the world. One of the most cited indicators used to describe and compare the impact of the pandemic in different Countries was **Case Fatality Rate (CFR)**: *the proportion of deaths between SARS-CoV-2 infection confirmed cases.*

- It is important to notice that this measure is strongly influenced by **the definition of *"confirmed cases"***. **Confounding** introduced by Country - specific testing policies can strongly impact on the interpretation of the results. This was the case when **comparing first-wave CFR between China and Italy!**

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Observing the Paradox

- For **all age groups**, **CFRs in Italy are lower** than those in China;
- But the **total CFR** in Italy is **higher** than that in China.

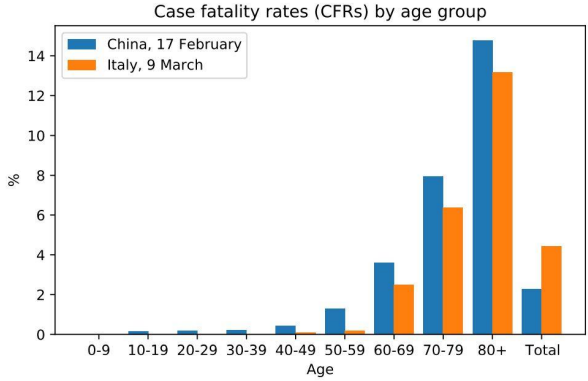


Figure: Simpson's paradox comparing CFR in Italy and China by age group.

Explaining the Paradox

Table 2: Proportion of confirmed cases from Table 1 by age group, larger proportion highlighted in bold.

Age	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	≥ 80
Italy	0.5%	1.0%	3.5%	5.6%	10.7%	17.4%	17.7%	**21.4%**	**18.4%**
China	**0.9%**	**1.2%**	**8.1%**	**17.0%**	**19.2%**	**22.4%**	**19.2%**	8.8%	3.2%

Table 3: Age demographic (of the general population) for Italy and China, larger proportion highlighted in bold.

Age	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	≥ 80
Italy	8.3%	9.5%	10.1%	11.6%	14.9%	**15.8%**	**12.4%**	**10%**	**7.5%**
China	**11.9%**	**11.6%**	**12.9%**	**15.9%**	**15%**	15.4%	10.5%	5%	1.8%

Table: Simpson's paradox is partially explained by the different age demographic, but the biggest difference is in the proportion of confirmed cases by age group.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Causal Inference

- In the context of a pandemic, you may want to evaluate and compare different strategies by asking **interventional** and **counterfactual** questions.
- What we observed by now, however, is only correlation data and ***"correlation does not imply causation"***, but there is a link between them.

Common cause principle

Any statistical dependence between two variables X and Y must have a causal explanation in that either *(i)* X causes Y, *(ii)* Y causes X, or *(iii)* X and Y have a common cause Z.

- Multiple **different causal models** could be employed with **different causal interpretations**: choosing a model is the first problem that needs to be address to answer to any causal question.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Causal Inference

- In the context of a pandemic, you may want to evaluate and compare different strategies by asking **interventional** and **counterfactual** questions.
- What we observed by now, however, is only correlation data and ***"correlation does not imply causation"***, but there is a link between them.

Common cause principle

Any statistical dependence between two variables X and Y must have a causal explanation in that either *(i)* X causes Y, *(ii)* Y causes X, or *(iii)* X and Y have a common cause Z.

- Multiple **different causal models** could be employed with **different causal interpretations**: choosing a model is the first problem that needs to be address to answer to any causal question.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Causal Inference

- In the context of a pandemic, you may want to evaluate and compare different strategies by asking **interventional** and **counterfactual** questions.
- What we observed by now, however, is only correlation data and ***"correlation does not imply causation"***, but there is a link between them.

Common cause principle

Any statistical dependence between two variables X and Y must have a causal explanation in that either *(i)* X causes Y, *(ii)* Y causes X, or *(iii)* X and Y have a common cause Z.

- Multiple **different causal models** could be employed with **different causal interpretations**: choosing a model is the first problem that needs to be address to answer to any causal question.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Causal Inference

- In the context of a pandemic, you may want to evaluate and compare different strategies by asking **interventional** and **counterfactual** questions.
- What we observed by now, however, is only correlation data and ***"correlation does not imply causation"***, but there is a link between them.

Common cause principle

Any statistical dependence between two variables X and Y must have a causal explanation in that either *(i)* X causes Y, *(ii)* Y causes X, or *(iii)* X and Y have a common cause Z.

- Multiple **different causal models** could be employed with **different causal interpretations**: choosing a model is the first problem that needs to be address to answer to any causal question.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Causal Model

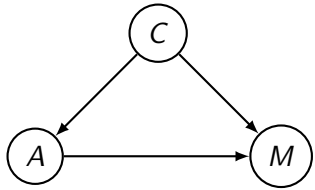


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

- C $\rightarrow$ A : age distribution of the confirmed cases depends on the Country,
- A $\rightarrow$ M : the disease is more dangerous in the elderly,
- C $\rightarrow$ M : country-specific influence on mortality other than age.
- **Assumptions**
  - Causal sufficiency (no hidden confounding).
  - CFR and age-distribution are based on an observational sample.

Causal Model

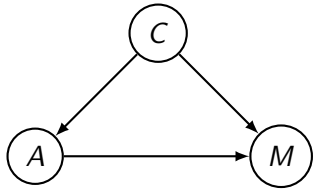


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

- $C \rightarrow A$: age distribution of the confirmed cases depends on the Country,
- $A \rightarrow M$: the disease is more dangerous in the elderly,
- $C \rightarrow M$: country-specific influence on mortality other than age.
- **Assumptions**
  - **Causal sufficiency** (no hidden confounding).
  - CFR and age-distribution are based on an **observational sample**.

Total Causal Effect (TCE)

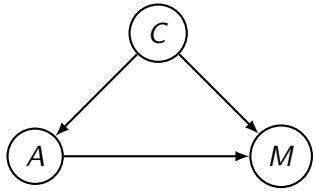


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *What would be the* ***effect on mortality*** *of changing country* ***from China to Italy?***
2. Average effect, influenced by the **different weights.**
3. The total causal effect (**TCE**):

$$TCE_{0\to 1} = \\ = \mathbb{E}[Y|do(T=0)] \\ - \mathbb{E}[Y|do(T=1)]$$

4. Overall, it looks **safer staying in China** instead of changing Country.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Total Causal Effect (TCE)

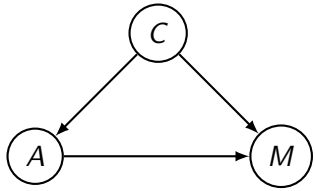


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *What would be the* ***effect on mortality*** *of changing country* ***from China to Italy?***
2. Average effect, influenced by the **different weights.**
3. The total causal effect (**TCE**):

$$TCE_{0\to 1} = \\ = \mathbb{E}[Y|do(T=0)] \\ - \mathbb{E}[Y|do(T=1)]$$

4. Overall, it looks **safer staying in China** instead of changing Country.

Total Causal Effect (TCE)

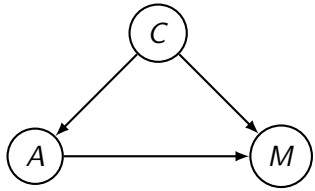


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *What would be the* ***effect on mortality*** *of changing country* ***from China to Italy?***
2. Average effect, influenced by the **different weights.**
3. The total causal effect (**TCE**):

$$TCE_{0\to 1} = \\ = \mathbb{E}[Y|do(T=0)] \\ - \mathbb{E}[Y|do(T=1)]$$

4. Overall, it looks **safer staying in China** instead of changing Country.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Total Causal Effect (TCE)

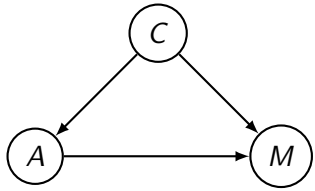


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *What would be the* ***effect on mortality*** *of changing country* ***from China to Italy?***
2. Average effect, influenced by the **different weights.**
3. The total causal effect (**TCE**):

$$
\begin{aligned}
TCE_{CN \to IT} = \\
&= \mathbb{E}[M|do(C = IT)] \\
&- \mathbb{E}[M|do(C = CN)] \\
&\approx 4.3\% - 2.3\% = 2\%
\end{aligned}
$$

4. Overall, it looks **safer staying in China** instead of changing Country.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Total Causal Effect (TCE)

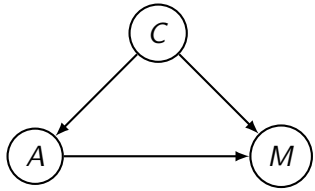


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *What would be the* ***effect on mortality*** *of changing country* ***from China to Italy?***
2. Average effect, influenced by the **different weights.**
3. The total causal effect (**TCE**):

$$
\begin{aligned}
&TCE_{CN \to IT} = \\
&= \mathbb{E}[M|do(C = IT)] \\
&- \mathbb{E}[M|do(C = CN)] \\
&\approx 4.3\% - 2.3\% = 2\%
\end{aligned}
$$

4. Overall, it looks **safer staying in China** instead of changing Country.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Mediation Analysis

- TCE does not help us understand ***what drives the difference***, the *mechanism* behind different CFRs.
- We need to better understand the role of age (A) as a mediator, to do that, we need to decompose the TCE of the Country (C) on mortality (M) between:
  - ***Direct effect*** through to the path

$$C \to M$$

  - ***Indirect effect***, mediated by A, through the path

$$C \to A \to M$$

- To estimate both *direct* and *indirect* effect we will use tools and concepts of **mediation analysis**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Section 2

Mediation Analysis

Controlled Direct Effect (CDE)

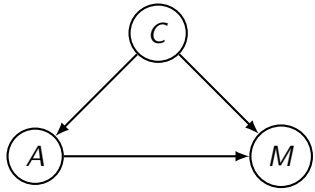


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For **50-59 year-olds**, is it safer to get the disease in China or in Italy?*
2. **Control the value** of the mediator.
3. The controlled direct effect (**CDE**):

$$CDE_{0\to 1}(z) = \\ = \mathbb{E}[Y|do(X=1,Z=z)] \\ - \mathbb{E}[Y|do(X=0,Z=z)]$$

4. For this age group **it is safer** to switch country to Italy.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Controlled Direct Effect (CDE)

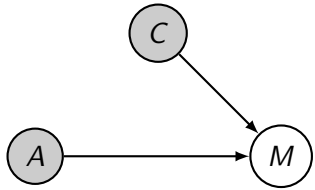


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For **50-59 year-olds**, is it safer to get the disease in China or in Italy?*
2. **Control the value** of the mediator.
3. The controlled direct effect (**CDE**):

$$CDE_{0\to 1}(z) = \\ = \mathbb{E}[Y|do(X=1,Z=z)] \\ - \mathbb{E}[Y|do(X=0,Z=z)]$$

4. For this age group **it is safer** to switch country to Italy.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Controlled Direct Effect (CDE)

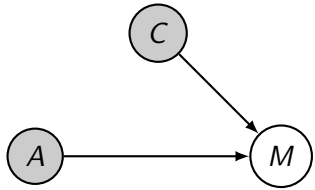


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For **50-59 year-olds**, is it safer to get the disease in China or in Italy?*
2. **Control the value** of the mediator.
3. The controlled direct effect (**CDE**):

$$CDE_{0\to 1}(z) = \\ = \mathbb{E}[Y|do(X=1,Z=z)] \\ - \mathbb{E}[Y|do(X=0,Z=z)]$$

4. For this age group **it is safer** to switch country to Italy.

Controlled Direct Effect (CDE)

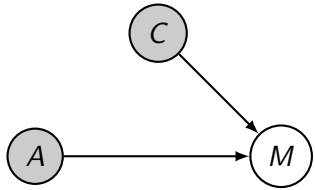


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For **50-59 year-olds**, is it safer to get the disease in China or in Italy?*
2. **Control the value** of the mediator.
3. The controlled direct effect (**CDE**):

$$
\begin{aligned}
&CDE_{CN \to IT}(\text{“}50-59\text{”}) = \\
&\quad = \mathbb{E}[M|do(C = IT, A = \text{“}50-59\text{”})] \\
&\quad - \mathbb{E}[M|do(C = CN, A = \text{“}50-59\text{”})] \\
&\quad \approx -1.1\%
\end{aligned}
$$

4. For this age group **it is safer** to switch country to Italy.

Controlled Direct Effect (CDE)

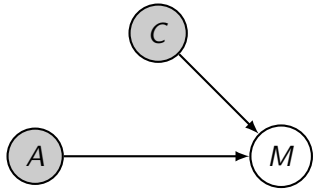


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For **50-59 year-olds**, is it safer to get the disease in China or in Italy?*
2. **Control the value** of the mediator.
3. The controlled direct effect (**CDE**):

$$
\begin{aligned}
&CDE_{CN \to IT}(\text{“}50-59\text{”}) = \\
&\quad = \mathbb{E}[M|do(C = IT, A = \text{“}50-59\text{”})] \\
&\quad - \mathbb{E}[M|do(C = CN, A = \text{“}50-59\text{”})] \\
&\quad \approx -1.1\%
\end{aligned}
$$

4. For this age group **it is safer** to switch country to Italy.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Natural Direct Effect (NDE)

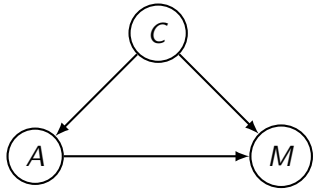


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For the **Chinese demographic** case, would it have been better to take the **Italian approach** instead?*
2. Rely on the **natural distribution** of the mediator **given the control**.
3. The natural direct effect (**NDE**):

$$NDE_{0\to 1} = \mathbb{E}[Y_{Z(X=0)}|do(X=1)] - \mathbb{E}[Y|do(X=0)]$$

where the subscript $Z(X=0)$ refers to the counterfactual distribution of Z had X been 0.

Natural Direct Effect (NDE)

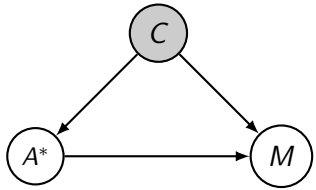


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For the **Chinese demographic** case, would it have been better to take the **Italian approach** instead?*
2. Rely on the **natural distribution** of the mediator **given the control**.
3. The natural direct effect (**NDE**):

$$NDE_{0\to 1} = \mathbb{E}[Y_{Z(X=0)}|do(X=1)] - \mathbb{E}[Y|do(X=0)]$$

where the subscript $Z(X=0)$ refers to the counterfactual distribution of Z had X been 0.

Natural Direct Effect (NDE)

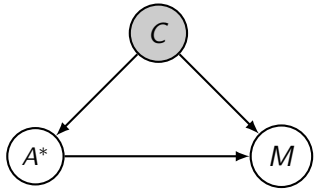


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For the **Chinese demographic** case, would it have been better to take the **Italian approach** instead?*
2. Rely on the **natural distribution** of the mediator **given the control**.
3. The natural direct effect (**NDE**):

$$NDE_{0\to 1} = \mathbb{E}[Y_{Z(X=0)}|do(X=1)] - \mathbb{E}[Y|do(X=0)]$$

where the subscript $Z(X=0)$ refers to the counterfactual distribution of Z had X been 0.

Natural Direct Effect (NDE)

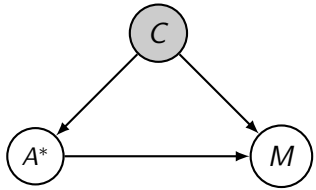


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For the **Chinese demographic** case, would it have been better to take the **Italian approach** instead?*
2. Rely on the **natural distribution** of the mediator **given the control**.
3. The natural direct effect (**NDE**):

$$
\begin{aligned}
&NDE_{CN \to IT} = \\
&\quad = \mathbb{E}[M_{A(C=CN)} | do(C = IT)] \\
&\quad - \mathbb{E}[M | do(C = CN)] \\
&\quad \approx -0.8\%
\end{aligned}
$$

4. Using the Italian approach would lead to a **reduction in total CFR**.

Natural Direct Effect (NDE)

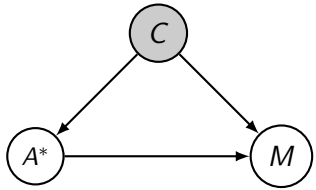


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *For the **Chinese demographic** case, would it have been better to take the **Italian approach** instead?*
2. Rely on the **natural distribution** of the mediator **given the control**.
3. The natural direct effect (**NDE**):

$$
\begin{aligned}
&NDE_{CN \to IT} = \\
&= \mathbb{E}[M_{A(C=CN)} | do(C = IT)] \\
&- \mathbb{E}[M | do(C = CN)] \\
&\approx -0.8\%
\end{aligned}
$$

4. Using the Italian approach would lead to a **reduction in total CFR**.

Natural Indirect Effect (NIE)

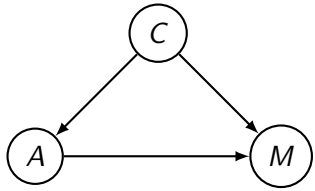


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *How would the **CFR in China** change if the case **demographic** had been that **from Italy**?*
2. Rely on **changing the natural distribution** of the mediator.
3. The natural indirect effect (**NIE**):

$$NIE_{0\to 1} = \mathbb{E}[Y_{Z(X=1)}|do(X=0)] - \mathbb{E}[Y|do(X=0)]$$

4. Changing only the case demographic **increase the CFR in China**.

Natural Indirect Effect (NIE)

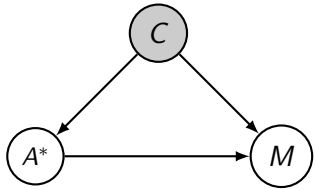


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *How would the **CFR in China** change if the case **demographic** had been that **from Italy**?*
2. Rely on **changing the natural distribution** of the mediator.
3. The natural indirect effect (**NIE**):

$$NIE_{0\to 1} = \mathbb{E}[Y_{Z(X=1)}|do(X=0)] - \mathbb{E}[Y|do(X=0)]$$

4. Changing only the case demographic **increase the CFR in China**.

Natural Indirect Effect (NIE)

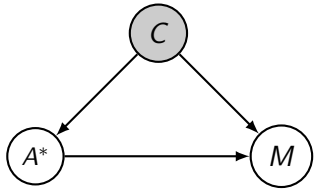


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *How would the **CFR in China** change if the case **demographic** had been that **from Italy**?*
2. Rely on **changing the natural distribution** of the mediator.
3. The natural indirect effect (**NIE**):

$$NIE_{0\to 1} = \\ = \mathbb{E}[Y_{Z(X=1)}|do(X=0)] \\ - \mathbb{E}[Y|do(X=0)]$$

4. Changing only the case demographic **increase the CFR in China**.

Natural Indirect Effect (NIE)

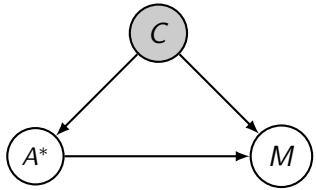


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *How would the **CFR in China** change if the case **demographic** had been that **from Italy**?*
2. Rely on **changing the natural distribution** of the mediator.
3. The natural indirect effect (**NIE**):

$$
\begin{aligned}
&NIE_{CN \to IT} = \\
&= \mathbb{E}[M_{A(C=IT)} | do(C = CN)] \\
&- \mathbb{E}[M_{A(C=CN)} | do(C = CN)] \\
&\approx +3.3\%
\end{aligned}
$$

4. Changing only the case demographic **increase the CFR in China**.

Natural Indirect Effect (NIE)

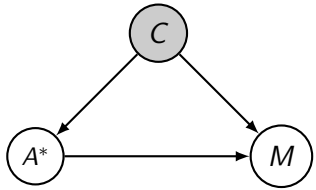


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *How would the **CFR in China** change if the case **demographic** had been that **from Italy**?*
2. Rely on **changing the natural distribution** of the mediator.
3. The natural indirect effect (**NIE**):

$$
\begin{aligned}
&NIE_{CN \to IT} = \\
&= \mathbb{E}[M_{A(C=IT)} | do(C = CN)] \\
&- \mathbb{E}[M_{A(C=CN)} | do(C = CN)] \\
&\approx +3.3\%
\end{aligned}
$$

4. Changing only the case demographic **increase the CFR in China**.

Interactions between TCE, NDE and NIE

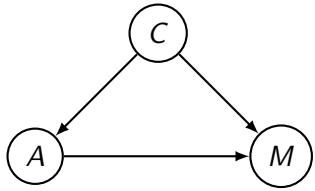


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *Can the total causal effect be* ***decomposed into a sum*** *of direct and indirect contributions?*

$$TCE_{0\to 1} \stackrel{?}{=} NDE_{0\to 1} + NIE_{0\to 1}$$

2. **True for simple linear models**, where causal effects correspond to path coefficients.
3. **False in general**, due to possible interactions between treatment and mediator in non-linear models.

Interactions between TCE, NDE and NIE

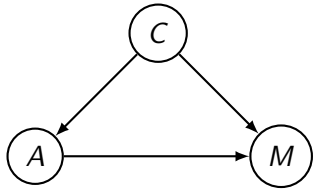


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *Can the total causal effect be **decomposed into a sum** of direct and indirect contributions?*
2. **True for simple linear models**, where causal effects correspond to path coefficients.

$$TCE_{0\to 1} = NDE_{0\to 1} + NIE_{0\to 1}$$

3. **False in general**, due to possible interactions between treatment and mediator in non-linear models.

Interactions between TCE, NDE and NIE

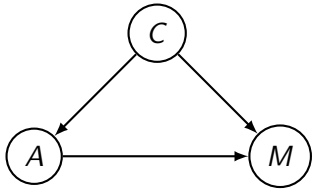


Figure: Assumed causal graph for the relationship between country C, age group A, and mortality M.

1. Q: *Can the total causal effect be **decomposed into a sum** of direct and indirect contributions?*
2. **True for simple linear models**, where causal effects correspond to path coefficients.
3. **False in general**, due to possible interactions between treatment and mediator in non-linear models.

$$TCE_{0\to 1} \neq NDE_{0\to 1} + NIE_{0\to 1}$$

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Case Study: CFR between China and Italy

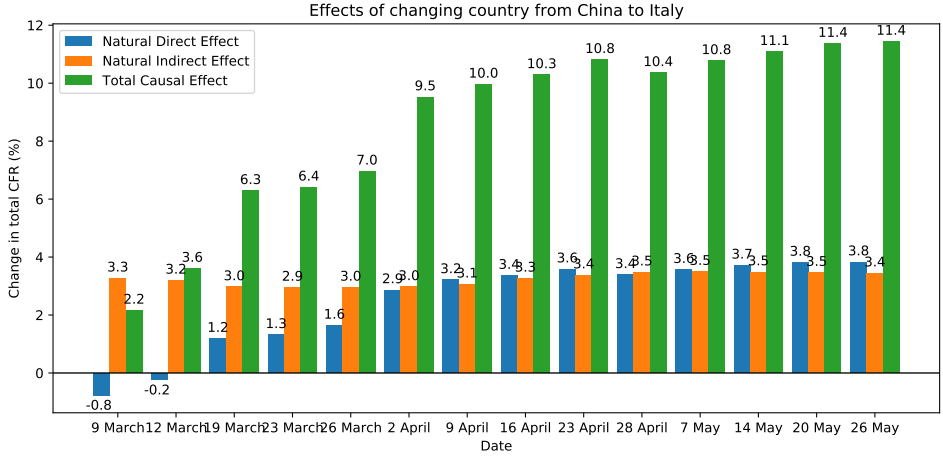


Figure: Evolution of TCE, NDE, and NIE of changing country from China to Italy on total CFR over time.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. **Over-whelmed healthcare** system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. **Over-whelmed healthcare** system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. Over-whelmed healthcare system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. **Over-whelmed healthcare** system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. **Over-whelmed healthcare** system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. **Over-whelmed healthcare** system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Discussions & Conclusions

1. **NDE flips sign**: switching increase the total CFR on the Chinese case demographic.
2. **NIE consistent** with the of cases amongst **elderly in Italy**.
3. **TCE grows more** quickly than the sum of NDE and NIE, indicating **moderation**.
4. **Over-whelmed healthcare** system in Italy?

Selection Bias

Elders are **more likely** to develop symptoms, **to get tested**, thus introducing bias.

Counterfactuals

Counterfactual reasoning can only be performed under **causal sufficiency**.

Additional Mediators

The virus is agnostic to "Countries": the influence on mortality is **mediated by other variables**.

Final considerations

- The article illustrated how mediation analysis can be used in a *real-world setting* to answer causal questions.
- The **strong assumptions** and the **oversimplified DAG** make the results interesting for educational purposes but difficult to be used to interpret the phenomena.
- To study first-wave pandemic data, **the changing over time** of the *"confirmed cases"* definition **within the Countries** should be taken into careful consideration.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Final considerations

- The article illustrated how mediation analysis can be used in a *real-world setting* to answer causal questions.
- The **strong assumptions** and the **oversimplified DAG** make the results interesting for educational purposes but difficult to be used to interpret the phenomena.
  - To study first-wave pandemic data, **the changing over time** of the *"confirmed cases"* definition **within the Countries** should be taken into careful consideration.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Final considerations

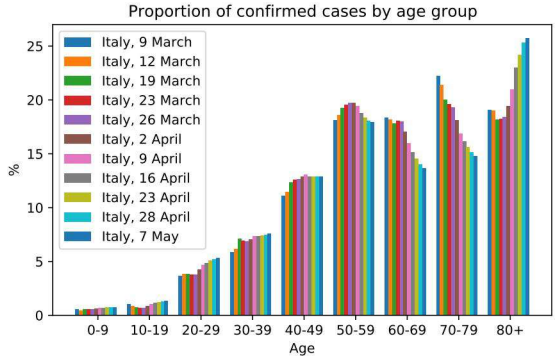
- The article illustrated how mediation analysis can be used in a *real-world setting* to answer causal questions.
- The **strong assumptions** and the **oversimplified DAG** make the results interesting for educational purposes but difficult to be used to interpret the phenomena.
- To study first-wave pandemic data, **the changing over time** of the *"confirmed cases"* definition **within the Countries** should be taken into careful consideration.

Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Final considerations

- The article illustrated how mediation analysis can be used in a *real-world setting* to answer causal questions.
- The **strong assumptions** and the **oversimplified DAG** make the results interesting for educational purposes but difficult to be used to interpret the phenomena.

- To study first-wave pandemic data, **the changing over time** of the *"confirmed cases"* definition **within the Countries** should be taken into careful consideration.



Introduction
General Overview
Simpson's Paradox
Inference
Model
TCE
Mediation
Mediation Analysis
CDE
NDE
NIE
Interactions
Case Study
Discussions
Considerations

Thank You for your Attention!

Alice Bernasconi <a.bernasconi6@campus.unimib.it>
Alessio Zanga <a.zanga3@campus.unimib.it>