Causal questions and principled answers

STRATOS TG 7

The simulation Learner

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- To show properties of a new method (e.g small sample behaviour)
- To compare the performance of different methods under different conditions
- To confirm calculations/analysis (i.e check (power) calculations, check an R-function)
- To get a deeper understanding of data and methods to analyse the data.

The Simulation Learner

TG 7 wrote tutorial on causal questions and principled answers

- Overview of causal concepts
- Overview of different analysis methods to deal with time fixed exposures

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Simulation Learner

- Simulated data based on an existing trial
- Illustrates concepts and methods on data

Promotion of Breastfeeding Intervention Trial - PROBIT

(Kramer et al, 2001)

- Pregnant women from low income area of Belarus, 1996-1997
- (cluster) randomised to
  - invitation for breast feeding encouraging educational program
  - no invitation

  during last term of pregnancy.
- Primary outcome: weight of baby at age 3 months.
- in total 17,044 women included
  (8,667 in the active arm and 8,377 in the control arm).

Many different causal questions of interest

Pregnant woman may ask about impact on weight at 3m of:

- following a BF program that is offered
- starting BF
- continuing BF for the full 3 months

in 'her' population stratum (e.g.highly educated, 30 year old, ...)

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Policy maker/health insurer may ask about impact on weight at 3m of:

- offering a BF encouragement program
- following the BF program
- starting BF
- continuing BF for a full 3 months

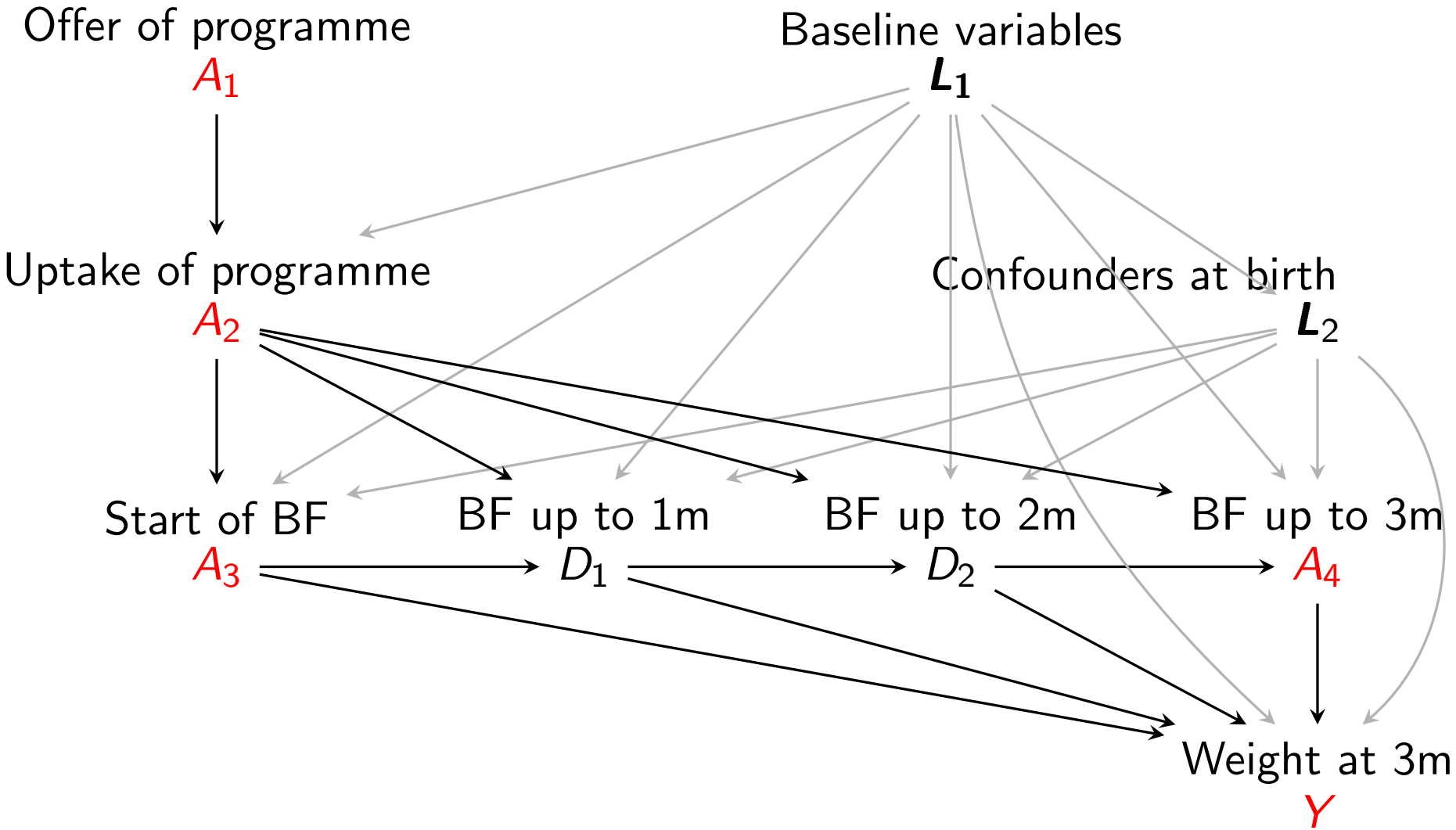
in different (targeted) population strata

We generated data inspired by PROBIT trial

- A simulated version of individually *randomised* women.
- 50 % received offer for the breast feeding educational programme
- 50 % received no offer
- Outcome: weight of baby after 3 months

Observed data is enriched by generation of potential outcome data

The data generation



Simulate potential intermediate events and outcomes

For each women:

- We simulated potential intermediate events
  - Will she take up the programme if she is invited?
  - Will she start breastfeeding if she is invited for the programmer?
  - Will she start breastfeeding without an offer
  - Will she start breastfeeding if she followed the program?

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  - Will she take up the programme if she is invited?
  - Will she start breastfeeding if she is invited for the programmer?
  - Will she start breastfeeding without an offer
  - Will she start breastfeeding if she followed the program?
- And potential outcomes under different "interventions"
  The weight of the baby after 3 months under
  - no offer
  - offer of the programme
  - following the programme
  - starting breastfeeding after following the programme
  - starting breastfeeding without a programme, etc

An example

Woman nr 7:

- 22, years old, higher educated, rural area, no smoker, baby boy with birth weight 2667 g
- $A_1 = 0$ She was randomized for control
- $A_2 = 0$ She did not follow the programme
- $A_3 = 0$ She did not start breastfeeding

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Potential intermediate events

- Would she take up the programme if she received an offer? YES

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Potential intermediate events

- Would she take up the programme if she received an offer? YES
- Would she start breastfeeding if she did receive an offer? YES, AND CONTINUE FOR 3 MONTHS

Potential outcomes for this woman

Weight of baby after 3 months

- Y_{obs} was 5813 grams

Potential outcomes

- $Y_{\mathfrak{a}_1(0)} = 5813g$, the potential outcome under no intervention.
- $Y_{\mathfrak{a}_1(1)} = 6133g$ the potential outcome under intervention.
- $Y_{\mathfrak{a}_2(1)} = 6133g$ the potential outcome under actually following the programme.
- $Y_{\mathfrak{a}_3(1),\mathfrak{a}_1(0)} = 6133g$ the potential outcome when she would start breastfeeding but not received an offer
- etc.

Mean potential weight at 3 months in all women under different treatments

outcome	interventions	population
$Y_{\mathfrak{a}_1(0)}$	programme not offered	6017
$Y_{\mathfrak{a}_1(1)}$	programme offered	6115
$Y_{\mathfrak{a}_2(1)}$	programme followed	6182

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Causal questions:

(i) What is the overall mean change in Y due to inviting expectant women to attend the BF program?
$\rightarrow$ ITT$=E(Y(\mathfrak{a}_1(1) - Y(\mathfrak{a}_1(0))=98$g

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(ii) What is the overall mean change in Y if all women would attend training?
$\rightarrow E(Y(\mathfrak{a}_2(1)) - Y(\mathfrak{a}_2(0)) = 165g$

Different (sub)populations could be of interest

Women:

(a) with babies for whom BF is not counter-indicated (overall population)

(b) who attended the training (the "treated")

(c) who would BF if invited to the training but not otherwise (the "BF compliers")

(d) from rural areas

Causal effects of different interventions in these subpopulations could be of interest

Mean potential weight at 3 months in treated and not treated

outcome	interventions	population	$A_1 = 1$ $A_2 = 1$	$A_1 = 1$ $A_2 = 0$
$Y_{\mathfrak{a}_1(0)}$	programme not offered	6017	6047	5964
$Y_{\mathfrak{a}_1(1)}$	programme offered	6115	6200	5964
$Y_{\mathfrak{a}_2(1)}$	programme followed	6182	6200	6149

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Causal questions:

(i) Among the women who followed the program, what estimated difference did it make (on average)?
ATT=Average treatment effect in the treated 6200-6047=153 g.

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Causal questions:

(i) Among the women who followed the program, what estimated difference did it make (on average)?
ATT=Average treatment effect in the treated 6200-6047=153 g.

(ii) And expected potential impact for women who did not follow the program? ATNT = 185 g

Methods to estimate these causal effects from observed data

Different approaches (with different assumptions, which may estimate different causal effects)

- Outcome regression
- Propensity score methods
- Instrumental Variables

- In R, Stata, and SAS

Gain in weight@3months, following the programme ($A_2 = 1$), versus no programme

Estimand	Estimation method	Estimate	(SE)
ATE			
	True value	165.1 g	
	Crude regression	196.0	(9.6)
	Regression adjustment (simple)	155.4	(9.5)
	Regression adjustment (with interactions)	165.0	(9.7)
	PS stratification* (6 strata)	165.0	(9.4)
	Regression with PS *	156.2	(9.0)
	PS matching (1 match)	155.7	(10.1)
	PS matching (3 matches)	154.9	(10.1)
	PS IPW	164.7	(9.7)
	PS Double robust IPW	164.7	(9.7)
	Instrumental variable	146.2	(14.0)

Results for A_3 (Starting breastfeeding)

	$A_1 = 0$		$A_1 = 1$	
Estimation method	Estimate	(SE)	Estimate	(SE)
ATE				
True value	386.8		422.3	
Crude regression	503.2	(11.6)	582.0	(12.2)
Regression (simple)	384.3	(2.8)	428.0	(3.3)
Regression (with interactions)	384.7	(3.2)	425.3	(2.7)
Regression with PS *	384.4	(3.2)	425.9	(3.3)
PS stratification* (6 strata)	392.2	(4.1)	442.0	(6.5)
PS matching (1 match)	386.5	(8.1)	429.0	(10.6)
PS matching (3 matches)	380.7	(5.5)	437.2	(7.8)
PS IPW	384.7	(3.8)	426.6	(6.7)
PS DR IPW	384.8	(3.9)	426.7	(7.0)
IV	513.3	(44.4)	–	–

Simulation learner is useful because:

- Generates dataset with observed data, augmented with potential outcomes
- Gives more insight in process of data generation
- Actual causal effects are known
- Great help in finding correct ways of analysis (which turned out to be different for A_2 and A_3)
- Enables to compare different analytic methods.
- It is helpfull in teaching causal methods
- Code of generation and analysis of data is available

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Causal Inference

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