Surveys with Julia

Introduction to Survey.jl

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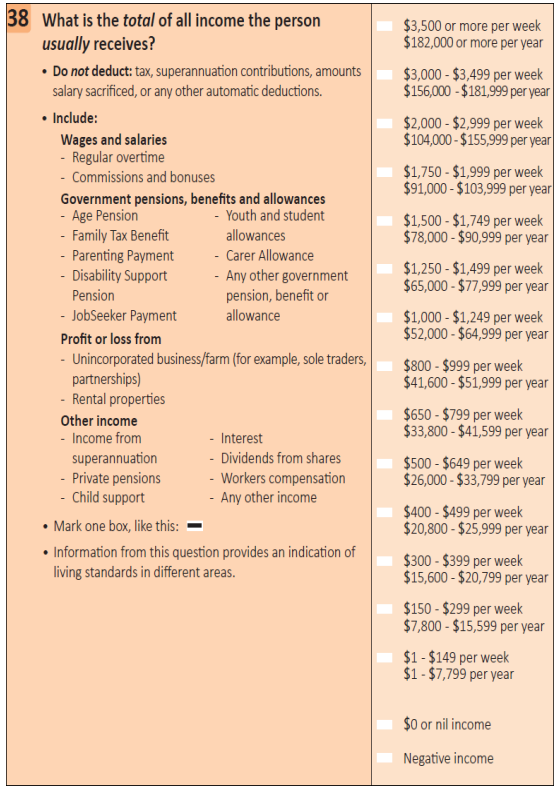
What is complex survey analysis?

- Surveys are an empirical tool for social and behavioural analysis
- **Goal:** obtaining estimates for a large population by surveying a well selected subset
- In contrast to a **census**
- Special techniques available for increasing precision and representation of the survey
  - Several types of survey "designs" and sampling methods



38 What is the *total* of all income the person *usually* receives?

- **Do *not* deduct:** tax, superannuation contributions, amounts salary sacrificed, or any other automatic deductions.
- **Include:**

Wages and salaries
- Regular overtime
- Commissions and bonuses

Government pensions, benefits and allowances
- Age Pension
- Family Tax Benefit
- Parenting Payment
- Disability Support Pension
- JobSeeker Payment
- Youth and student allowances
- Carer Allowance
- Any other government pension, benefit or allowance

Profit or loss from
- Unincorporated business/farm (for example, sole traders, partnerships)
- Rental properties

Other income
- Income from superannuation
- Private pensions
- Child support
- Interest
- Dividends from shares
- Workers compensation
- Any other income

- Mark one box, like this: ▬
- Information from this question provides an indication of living standards in different areas.

- $3,500 or more per week
  $182,000 or more per year
- $3,000 - $3,499 per week
  $156,000 - $181,999 per year
- $2,000 - $2,999 per week
  $104,000 - $155,999 per year
- $1,750 - $1,999 per week
  $91,000 - $103,999 per year
- $1,500 - $1,749 per week
  $78,000 - $90,999 per year
- $1,250 - $1,499 per week
  $65,000 - $77,999 per year
- $1,000 - $1,249 per week
  $52,000 - $64,999 per year
- $800 - $999 per week
  $41,600 - $51,999 per year
- $650 - $799 per week
  $33,800 - $41,599 per year
- $500 - $649 per week
  $26,000 - $33,799 per year
- $400 - $499 per week
  $20,800 - $25,999 per year
- $300 - $399 per week
  $15,600 - $20,799 per year
- $150 - $299 per week
  $7,800 - $15,599 per year
- $1 - $149 per week
  $1 - $7,799 per year
- $0 or nil income
- Negative income

Survey terminology and techniques

Weighting How many people does each respondent represent?

Strata Subgroups of the population known a priori eg. states, districts, gender. Strata info used to improve representation

Clusters Logistical constraints on survey sampling, can only visit n states, districts and suburbs

Why does a "survey analysis" package do?

- Computing summary statistics from a survey requires applying mathematical corrections and adjustments
  - eg. population mean is not as simple as arithmetic mean of a numeric vector
- Point estimates (relatively) easy, variance estimation is hard
- A "survey" package exposes an intuitive API to user, and automatically applies formulae and corrections in background
  - In Survey.jl, for population mean (with SE) of a variable you can do `mean(:variable,data)`

Our engineering journey

- Users of R `survey` package
  - Benchmark for open-source complex survey analysis
  - CMIE CPHS, Prowess, NFHS etc
- R ‘survey‘ designed in early 00’s for MB’s of data
  - slow for ”large” modern datasets and many class of simulation problems
  - eg. variance estimation using bootstrapping
  - Computation times upto few hours for simple summary statistics
- Real-world performance a key factor in development of `Survey.jl`

Why Julia for complex survey analysis

Performance **Expressivity** of R/Python meets **speed** of a systems language

Community Several unmaterialised attempts to create survey analysis package. We received feedback and even contributing PRs. 1

Development Avoid "two-language problem". Survey researchers just want something that works great out of the box. Easy maintenance.

Ecosystem Julia has substantial statistical computing abilities, with state of the art `DataFrames`, `Makie`, `Optim`, `Turing`, `Flux`, `LinearAlgebra` packages. `Survey` is complement to and complemented by the entire data ecosystem.

Survey.jl

An efficient computing framework for survey analysis

- Summary statistics - `mean`, `total`, `ratio`, and `quantile`
- Subpopulations / domain estimation for subsets of sample
- Variance estimation using Rao-Wu bootstrap
  - Using Julia, 1k MC simulations in same time that R does 50 trials.
- Visualisations support for weighted scatter plots, histograms and boxplots
- Tested and compared against R `survey`

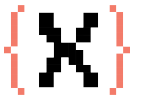
Getting started with Survey.jl GitHub and Documentation

Demo workflow

Import and load data

Survey: CMIE Consumer Pyramids Household Survey - Multistage stratified high frequency survey of Indian households

```
# Imports and housekeeping
...
# Connect to SQL server
conn = DBInterface.connect(MySQL.Connection, host, user,
  ↪  password; db = "hhd")
query = "SELECT RESPONSE_STATUS, STATE, HR, DISTRICT,
  ↪  STRATUM, PSU_ID, REGION_TYPE, FAMILY_SHIFTED, HH_ID,
  ↪  MONTH_SLOT, MONTH, TOTAL_INCOME , HH_WEIGHT_MS,
  ↪  HH_NON_RESPONSE_MS  FROM hh_income_monthly WHERE MONTH
  ↪  = 'Apr 2022' AND RESPONSE_STATUS = 'Accepted'"
# Pipe query output into DataFrame
df = DBInterface.execute(conn, query) |> DataFrame
```



Demo workflow

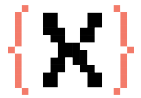
Create SurveyDesign

```
# Load df into survey design object
julia> CPHS_income = SurveyDesign(df, clusters = :HH_ID,
 ↪  strata = :STRATUM, weights = :HH_WEIGHT_MS)

SurveyDesign:
data: 123816×17 DataFrame
strata: STRATUM
    [HR 1_URBAN_S, HR 1_URBAN_S,  …  HR 110_RURAL_R]
cluster: HH_ID
    [5.3877505e7, 4.3406519e7  …  6.742216e7]
popsize: [8.81791619977e7  …  1.034108342135e8]
sampsize: [123816, 123816, 123816  …  123816]
weights: [712.1791, 712.1791, 712.1791  …  835.1977]
allprobs: [0.0014, 0.0014, 0.0014  …  0.0012]
```

Demo workflow

Create ReplicateDesign

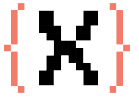
```
# Create replicate design using Rao-Wu bootstrap weights
julia> CPHS_income_bootstrap = bootweights(CPHS_income,
 ↪  replicates = 500)

ReplicateDesign:
data: 123816×517 DataFrame
strata: STRATUM
    [HR 1_URBAN_S, HR 1_URBAN_S  …  HR 102_URBAN_M]
cluster: HH_ID
    [1.0034716e7, 1.0190136e7  …  9.9842237e7]
popsize: [8.81791619977e7  …  2.92096840303e7]
sampsize: [123816, 123816, 123816  …  123816]
weights: [712.1791, 712.1791, 712.1791  …  235.912]
allprobs: [0.0014, 0.0014, 0.0014  …  0.0042]
replicates: 500
```



Demo workflow with CPHS

Calculate summary statistics

```
# Mean income
julia> mean(:TOTAL_INCOME, CPHS_income_bootstrap)
1×2 DataFrame
 Row   mean      SE
       Float64   Float64

   1   23870.2   81.8377

# Mean income by strata (Subpopulation estimation)
julia> mean(:TOTAL_INCOME, :HR, CPHS_income_bootstrap)
102×3 DataFrame
 Row   HR        mean      SE
       String    Float64   Float64

   1   HR 1      33040.2   574.598
   2   HR 2      28362.1   827.503
   3   HR 3      19109.1   595.618
  ...   ...         ...       ...
 101   HR 95     15571.7   490.704
 102   HR 97     12804.6   249.971
                    96 rows omitted
```



Future Plans

Efficient implementations of all the methods in R ‘survey‘. Features for future releases will include:

- Proportion and count estimation
- Variance by Taylor linearization for ‘SurveyDesign‘
- More replicate weighting algorithms (BRR, Jackknife, other types of bootstrap) for ‘ReplicateDesign‘
- Post-stratification, raking, calibration, GREG estimation
- Frequency/contingency table analysis, association tests
- Missing data handling (like R mitools)
- Integration with survival analysis tools
- Integration with GLM.jl
- Out-of-memory integration with SQL databases

Appendix

- Julia Discourse posts here and here
- Unmaterialised attempts samplics/survey.jl and jamanrique/SurveyAnalysis.jl

Thank you.

https://xkdr.org