Incorporating Misclassification into Capture-Recapture Methodology in the 2012 Census of Agriculture

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Census of Agriculture: history

- Conducted in years ending in 2 and 7.
- Before 1997: U.S. Census Bureau
- 1997-present: USDA/NASS

Census of Agriculture: purpose

- Quantity of interest: number of farms
  - State
  - Farm type
  - Race
  - Gender
- Factor in allocation of funds for Federal agriculture programs
  - e.g. land grant universities

Farm definition

- Target population: operations that meet USDA farm definition.
- An agricultural operation that either
  - Produces at least $1,000 of sales in a year,
  - Normally produced $1,000 in sales,
  - OR 1,000 points of agricultural items

Examples of Point Farms

- 5 horses
- 1 acre of Christmas trees
- 100 acres of pasture land
- $1,000 in government payments

Documented farm misclassification

- Farm Numbers Research Project (2009): tracts in June Area Survey (JAS) were incorrectly identified as non-agricultural when agriculture was present.
- Classification Error Survey following 2007 Census: classification errors made during both Census and JAS.
- June Area Survey (JAS): used as supplemental survey to Census for farm number estimation.

Purpose of talk

- Accounting for farm misclassification in 2012 Census of Agriculture
- Adjusts traditional methodology
  - Dual System Estimation (DSE)
  - Capture-recapture

Dual system estimation or capture-recapture methodology

- Similar methodologies in different contexts (in this presentation, used interchangibly)
- DSE
  - U.S. Census of Population
  - UK Census Coverage Assessment
- Capture-recapture
  - fish and wildlife populations

Main ideas of DSE and capture-recapture

- DSE
  - supplementary (independent) survey to quantify Census undercount
  - i.e. What proportion of units from the supp. survey are counted by the Census?
- Capture-recapture
  - Capture, tag, and return
  - Recapture
  - What proportion of animals captured in second catch are tagged from first catch?

Example: catching trout (taken from UK Census documentation)

- Day One: catch 100 trout. Tag each and release
- Day Two: catch 50 trout. 25 have tags.
- Estimate of total

$$\hat{N} = 100\left(\frac{25}{50}\right)^{-1} = 200$$

Analogy between DSE and capture-recapture

Capture-recapture	DSE
Day one catch	Records counted by the Census
Day two catch	Records counted by supp. survey
Tagging process	Matching of Census and survey records

$$\hat{N} = N_{Census}\left(\frac{N_{Census\&Supp.S}}{N_{Supp.S}}\right)^{-1}$$

Supp. Survey: June Area Survey

DSE for Census of Agriculture

- Challenge: traditional DSE does not deal with misclassification errors
- Census of Agriculture has 4 types of enumeration errors, including
  - under-coverage
  - non-response
  - 2 types of misclassification.

Errors in Enumeration Process

- List under-coverage: the omission of farms from the Census Mailing List (CML)
- Non-response: The failure of farm operators to return a completed Census questionnaire.
- Both conditioned on farms

Errors in Enumeration Process II

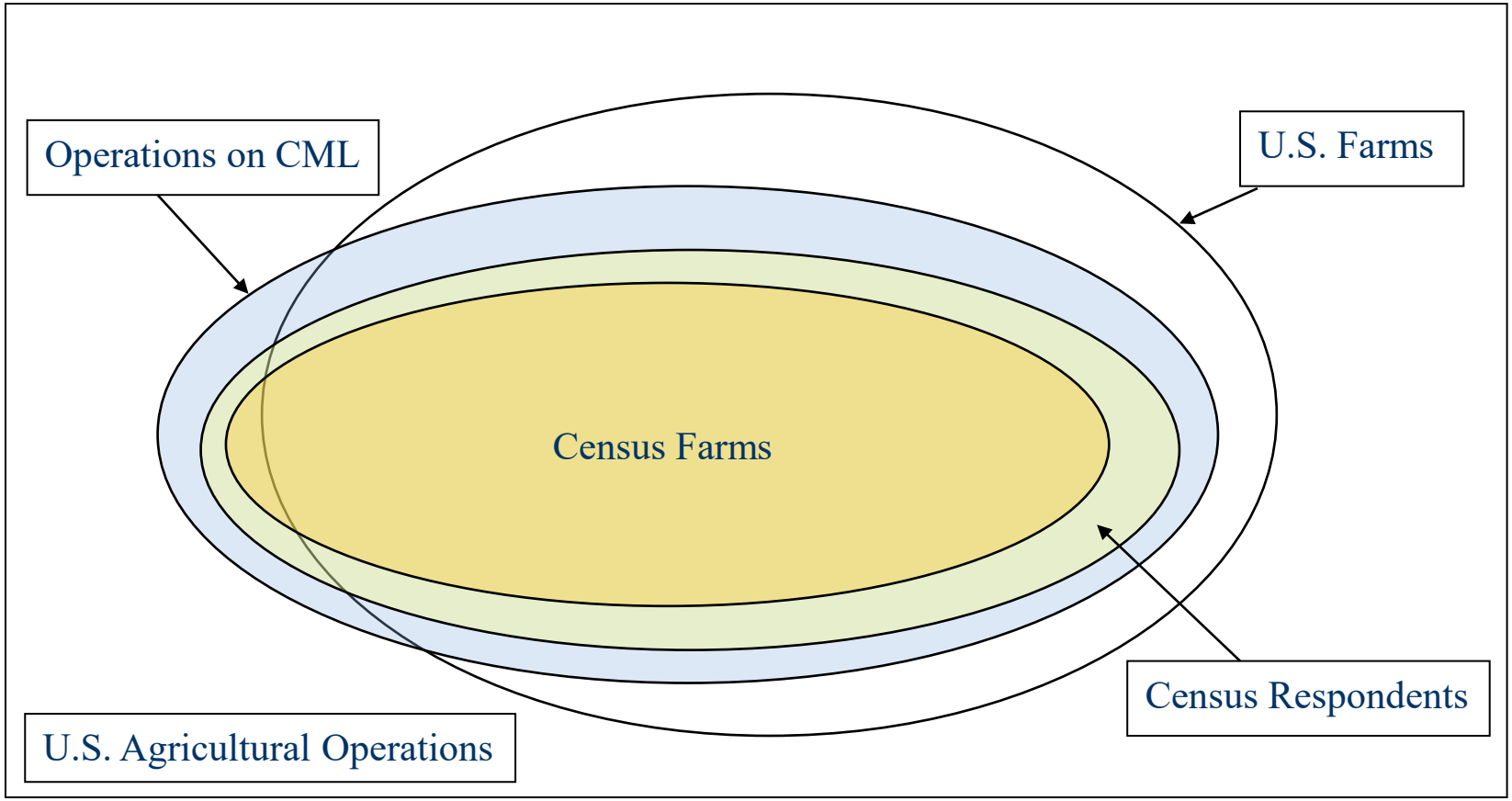
- Misclassification: Errors in Census reporting cause two types of misclassification errors:
  - Farms are classified as non-farms
  - Non-farms are classified as farms

Summary of Enumeration Errors

1. CML under-coverage of farms
2. Farm non-response
3. Farms are misclassified as Census non-farms
4. Non-farms are misclassified as Census farms

1-3: undercount, 4: overcount

Venn Diagram



Adjustments to traditional DSE

- Probability of farm imputed for unresolved records: where Census and JAS disagree on farm status
- Three undercount errors are combined into “capture”
- Account for “differential catchability”
- Correct for misclassification overcount

Definition of Capture

- An operation is “captured” by the Census if it is
  - on CML | Farm
  - Responds | CML, Farm
  - Classified as Census Farm | CML, Responds, Farm

Product of probabilities

P(capture) = P(on CML | Farm)
x P(Responds | CML, Farm)
x P(Classified as Census Farm | CML, Responds, Farm)

Or

$$p_{Cap} = p_{Cov} p_{\mathrm{Re}sp} p_{CCF}$$

Dual System Estimation

- Dual System Estimator using capture:

$$\hat{N} = \left(\frac{F_{JC}}{F_J} \right)^{-1} F_C$$

  - F_{JC}: number of farms captured by JAS and Census
  - F_J: number of farms captured by JAS
  - F_C: number of farms captured by Census

Two problems with first-adapted DSE

- Doesn’t account for heterogeneity in capture probabilities
- Doesn’t account for misclassification of non-farms as Census farms (overcount)

Example: Heterogeneity in capture probabilities

- Catching trout, roach, and catfish.

	First day catch, #Tagged	Second day catch, Fraction tagged	Estimate of Total
Trout	100	25/50	200
Roach	50	5/20	200
Catfish	10	1/10	100
All fish	160	31/80	413

- Account for differential capture rates = 500
- Don’t account = 413

Heterogeneity in capture probabilities: estimator

- Partition farms into groups so that the probability of capture is about the same within each group.
- Example: by state, farm sales, farm type, race, gender
- Sum DSE's for each group

$$\hat{N} = \sum_{i=1}^{n\_groups} \left(\frac{F_{JC,i}}{F_{J,i}} \right)^{-1} F_{C,i}$$

Logistic regression

- Logistic regression extends this approach: allows
  - continuous variables
  - more complex models.
- Each Census record has its own capture probability.

$$\hat{N} = \sum_{j=1}^{n\_records} p_{Cap,j}^{-1}$$

Logistic regression

- The 0/1 capture indicators Y_i follow a Bernoulli(π_{Ci}) distribution, where

$$\pi_{Ci} = \text{logit}^{-1}(x_{Ci}'\beta_C)$$

- β_C is estimated using the matched dataset (of JAS and Census)
- Then Census record probabilities of capture are

$$p_{Cj} = \text{logit}^{-1}(x_{Cj}'\hat{\beta}_C)$$

Two problems with traditional DSE

- Doesn’t account for heterogeneity in capture probabilities
- Doesn’t account for misclassification of non-farms as Census farms (overcount)

Adjustment for Misclassification

- The probability of correct Census farm classification is

  p_{CCFC} = P(Farm | Census Farm)

- Multiplied by capture weights to correct for overcount.

$$\hat{N} = \sum_{j=1}^{n\_records} \frac{p_{CCFC,j}}{p_{Cap,j}}$$

Final estimator

- The final estimator is obtained after expanding the capture probability into its components.

$$\hat{N} = \sum_{j=1}^{n\_records} \frac{p_{CCFC,j}}{p_{Cov,j}\, p_{\mathrm{Re}sp,j}\, p_{CCF,j}}$$

Computing probabilities

- The 4 probabilities
  - p_{Cov} = P(on CML | Farm)
  - p_{Resp} = P(Responds | CML, Farm)
  - p_{CCF} = P(Classified as Census farm | CML, Responds, Farm)
  - p_{CCFC} = P(Farm | Census farm)
- use different subsets of the matched dataset depending on the conditions.

Wrap-up

- Census of Agriculture
- Adjusts traditional DSE/capture-recapture methods for misclassification.

Thank you!