Study on the Limits of Data Disaggregation in Household Surveys for Population Subgroups and Geographical Areas and the Requirements to Overcome them

Application to poverty mapping in Palestine

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BASIC TERMINOLOGY

- **Areas/domains:** Subpopulations.
- **Direct estimator:** Based on survey data for the target area/domain.
- **Small area:** Area/domain for which the considered direct estimator of the target indicator is inefficient (too large sampling error).

POVERTY AND INEQ. INDICATORS

- E_{dj} **welfare** measure for indiv. j in domain d.
- $z =$ poverty line.
- **FGT poverty indicator of order α for domain d:**

$$F_{\alpha d} = \frac{1}{N_d} \sum_{j=1}^{N_d} \left(\frac{z - E_{dj}}{z} \right)^{\alpha} I(E_{dj} < z), \quad \alpha \geq 0.$$

- When $\alpha = 0 \Rightarrow$ **Poverty incidence** (or at-risk-of-poverty rate)
- When $\alpha = 1 \Rightarrow$ **Poverty gap**
- **Other:** Quintile share ratio, Gini coef., Sen index, Theil index, Generalized entropy, Fuzzy monetary/supplementary index.

✓ *Foster, Greer & Thornbecke (1984), Econom.*
✓ *Neri, Ballini & Betti (2005), Stat. in Transition*

DIRECT ESTIMATORS

- FGT pov. indicator as a mean:

$$F_{\alpha d} = \frac{1}{N_d} \sum_{j=1}^{N_d} F_{\alpha dj}, \quad F_{\alpha dj} = \left(\frac{z - E_{dj}}{z} \right)^{\alpha} I(E_{dj} < z)$$

- Direct estimators:

$$\hat{F}^{DIR}_{\alpha d} = \frac{1}{\sum_{j \in s_d} w_{dj}} \sum_{j \in s_d} w_{dj} F_{\alpha dj}, \quad \hat{F}^{S}_{\alpha d} = \frac{1}{n_d} \sum_{j \in s_d} F_{\alpha dj}.$$

- Very **inefficient** (unstable) for small n_d. Estimates can be **zero** for several areas!

INDIRECT ESTIMATION

- **Indirect estimator:** It **borrows strength** from other areas by making some kind of **homogeneity** assumption across areas (model with **common** parameters) that uses **auxiliary information**.
- **Synthetic estimators:** Do not allow for between-area heterogeneity beyond that explained by covariates.
- **Non-Synthetic estimators:** Do incorporate between-area heterogeneity beyond that explained by covariates.

NESTED ERROR MODEL

- The distribution of expenditures E_{dj} is highly right skewed.
- Select a transformation $T()$ such that the distribution of $y_{dj} = T(E_{dj})$ is approximately Normal.
- **Assumption:** $y_{dj} = T(E_{dj})$ satisfies the **nested error model**:

$$y_{dj} = \mathbf{x}'_{dj}\boldsymbol{\beta} + u_d + e_{dj}, \quad j = 1, \ldots, N_d, \; d = 1, \ldots, D$$

$$u_d \overset{iid}{\sim} N(0, \sigma_u^2), \quad e_{dj} \overset{iid}{\sim} N(0, \sigma_e^2)$$

✓ *Battese, Harter & Fuller (1988), JASA*

EB METHOD FOR POVERTY ESTIMATION

- Poverty indicators in terms of $\mathbf{y}_d = (y_{d1}, \ldots, y_{dN_d})'$:

$$F_{\alpha d} = \frac{1}{N_d} \sum_{j=1}^{N_d} \left\{ \frac{z - T^{-1}(y_{dj})}{z} \right\}^{\alpha} I\left\{ T^{-1}(y_{dj}) < z \right\} = h_{\alpha}(\mathbf{y}_d).$$

- Partition $\mathbf{y}_d$ into sample and out-of-sample: $\mathbf{y}_d = (\mathbf{y}'_{ds}, \mathbf{y}'_{dr})'$
- **Best predictor:** Minimizes the MSE

$$\tilde{F}^{B}_{\alpha d} = E_{\mathbf{y}_{dr}} \left[F_{\alpha d} | \mathbf{y}_{ds}; \boldsymbol{\beta}, \sigma^2_u, \sigma^2_e \right].$$

- **Empirical best (EB) predictor:** $\hat{F}^{EB}_{\alpha d} = \tilde{F}^{B}_{\alpha d}(\hat{\boldsymbol{\beta}}, \hat{\sigma}^2_u, \hat{\sigma}^2_e)$.

✓ *Molina and Rao (2010), CJS*

DATA DESCRIPTION

- **Data:** Palestinian Expenditure Consumption Survey (PECS) from 2016/2017 and Population Census from 2017.
- **Target:** Estimate poverty rates and gaps for Palestinian localities by gender.
- **Areas:** In census, 319 **localities**$\rightarrow D = 162$ in survey. We compute estimates for each **sampled** locality by gender.
- **Welfare measure:** E_{dj} monthly expenditure per adult equivalent (ILS).
- **Poverty line:** $z = 10,027$ ILS $\rightarrow$ approx. **26 %** popn. below pov. line.

SAMPLE SIZES

- Sample size: $n = 18,363$ out of $N = 4,266,953$ (43 out of 10,000).

	Women	Men	Total
Gaza	2569	2578	5147
West Bank	6550	6666	13216
Total	9119	9244	18363

- Sample sizes of localities by gender:

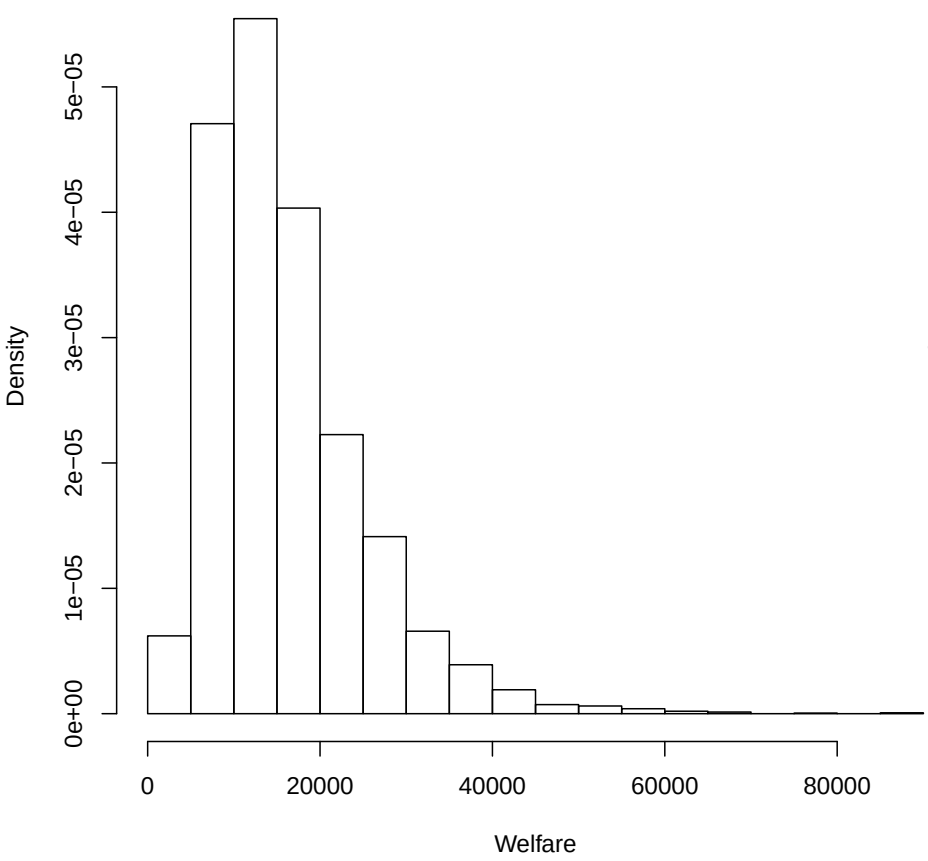
	Min	1st Qu	Median	Mean	3rd Qu.	Max
Women	14.00	26.00	35.00	56.29	61.50	405.00
Men	13.00	28.00	36.00	57.06	63.00	464.00

FITTED MODEL

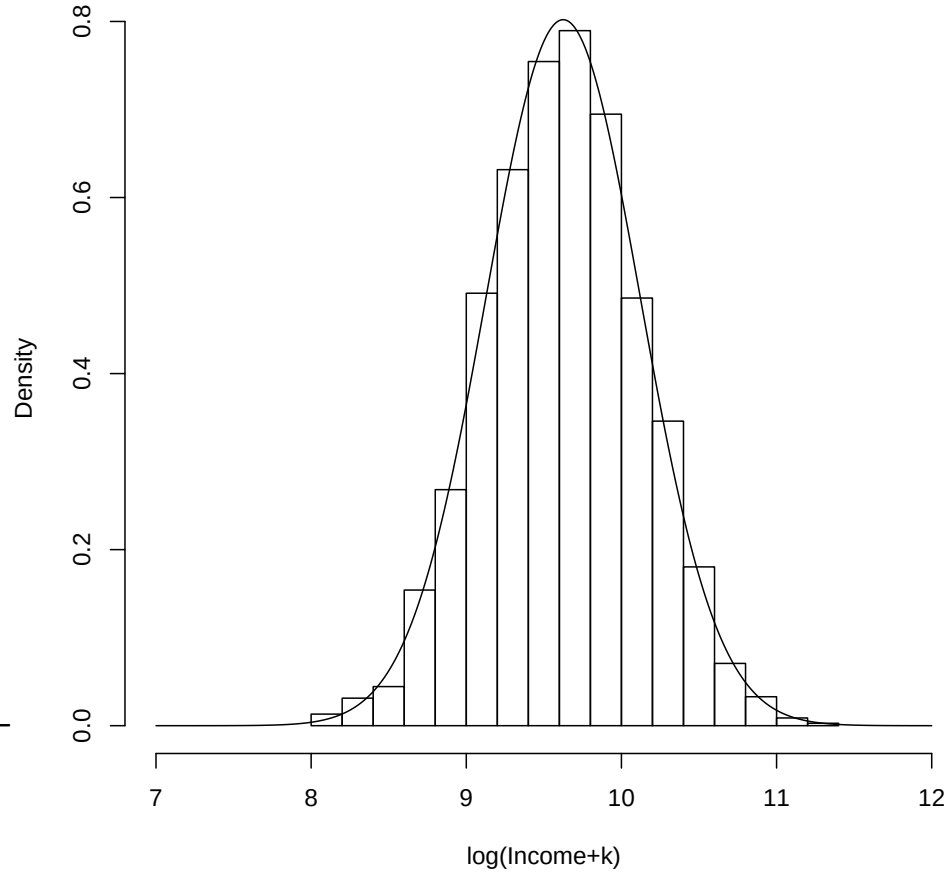
- We fit a separate model for each gender.
- **Transformation:** We consider the nested-error model for the log of expenditure: $y_{dj} = T(E_{dj}) = \log(E_{dj} + k)$.
- **Explanatory variables:**
  - ✓ Indicators of region (Gaza, West Bank), type of locality (rural/urban, camp).
  - ✓ Household characteristics (size, prop. females, employed ratio).
  - ✓ Household head characteristics (unemployed, employisrasett, employnatgov, refugstat, diff, neverschool, secondabove).
  - ✓ Dwelling characteristics (type, tenure, num. rooms).
  - ✓ Supplies (water, waste, heating systems, freezer, etc.)
- **Fitting results:** All covariates with significant categories for both genders.
- **Explanatory power:** $R^2 = 53.6\,\%$, both genders.

NORMALITY EXPENDITURE

Original scale

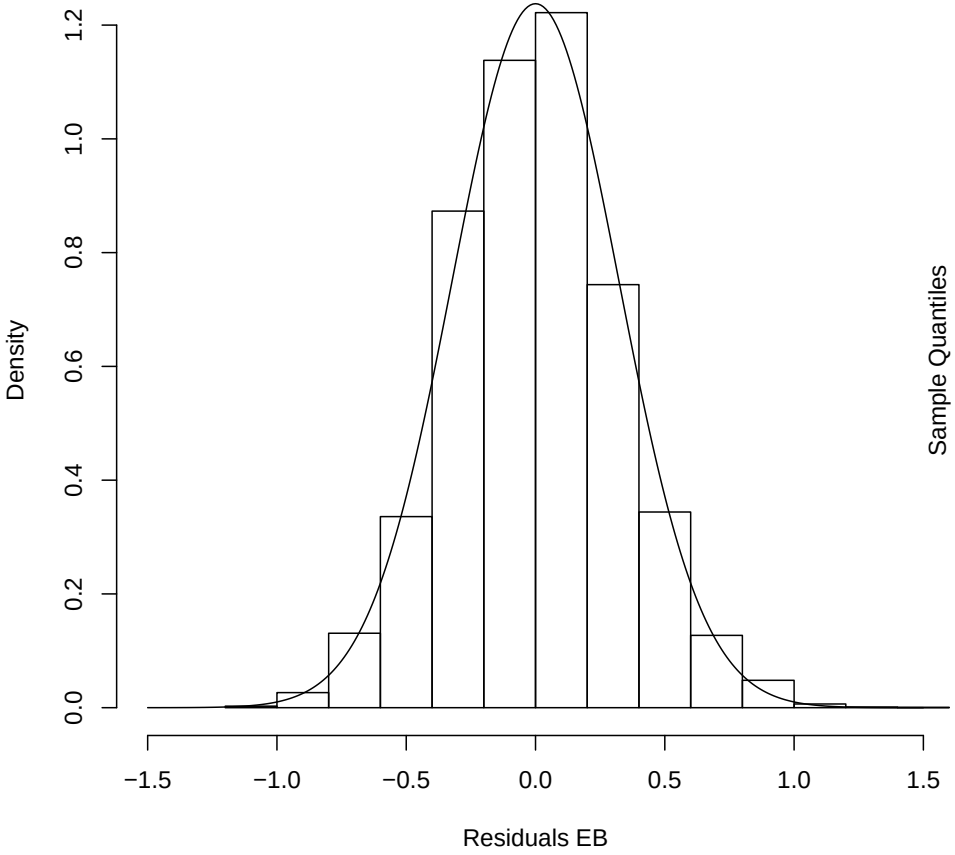


Log-scale after shift

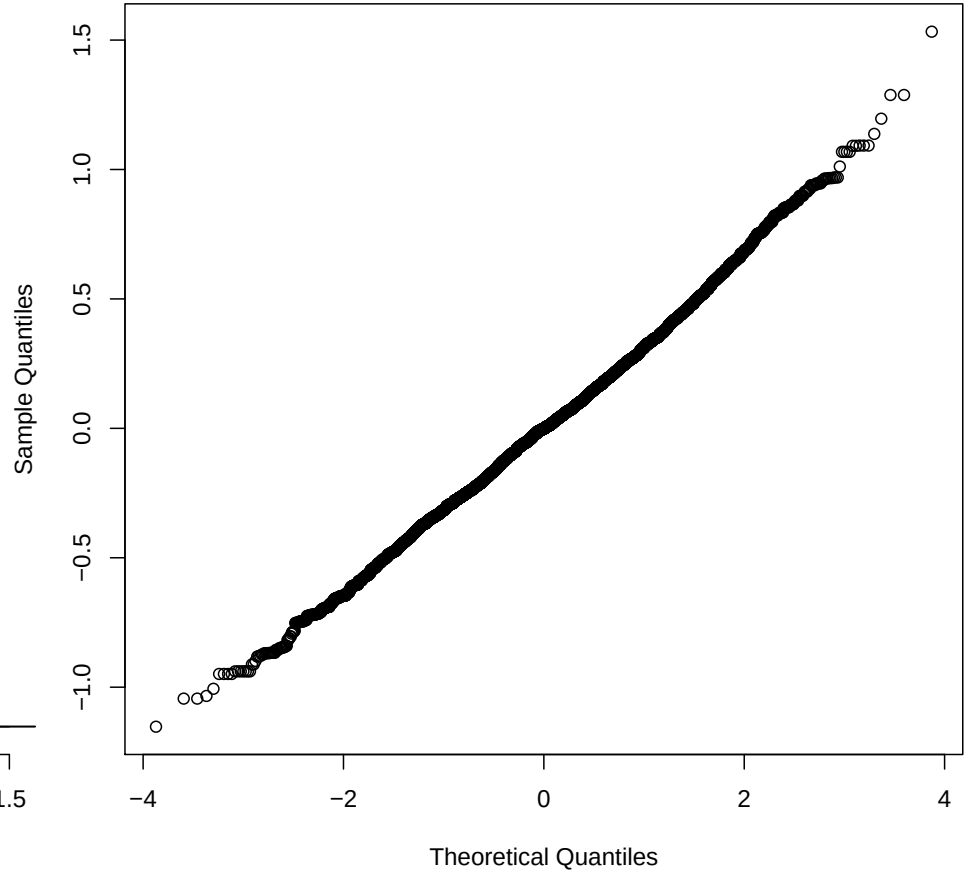


NORMALITY UNIT LEVEL RESIDUALS

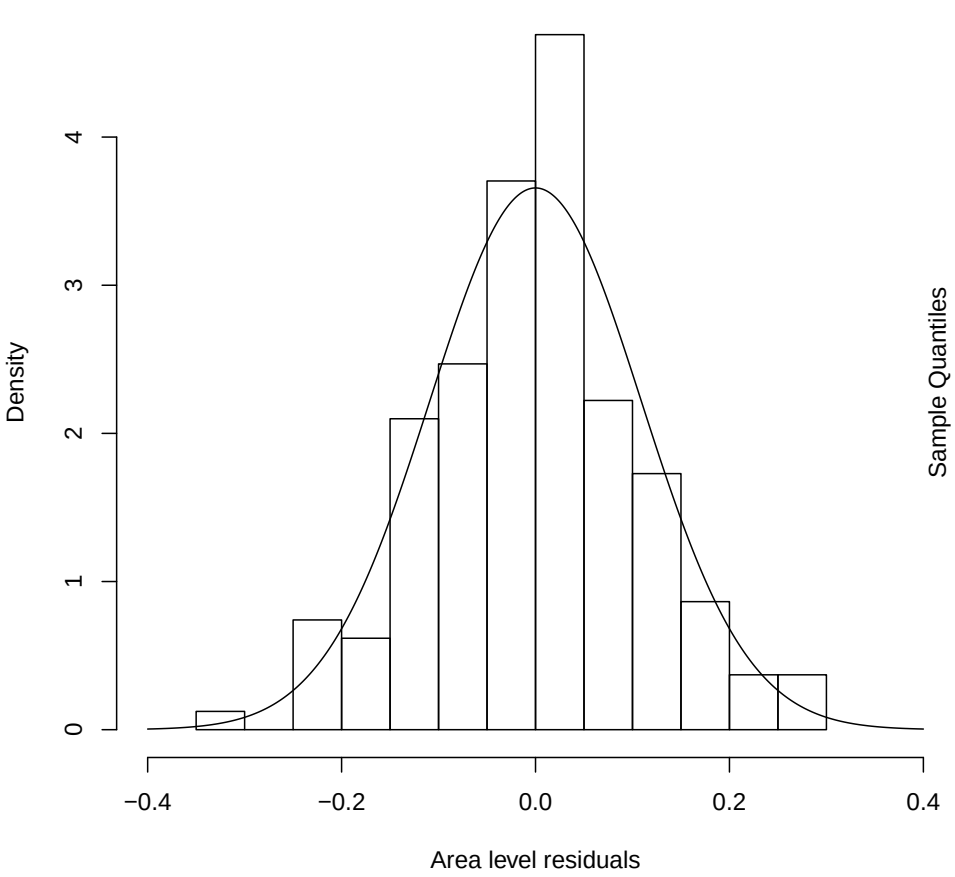
Histogram

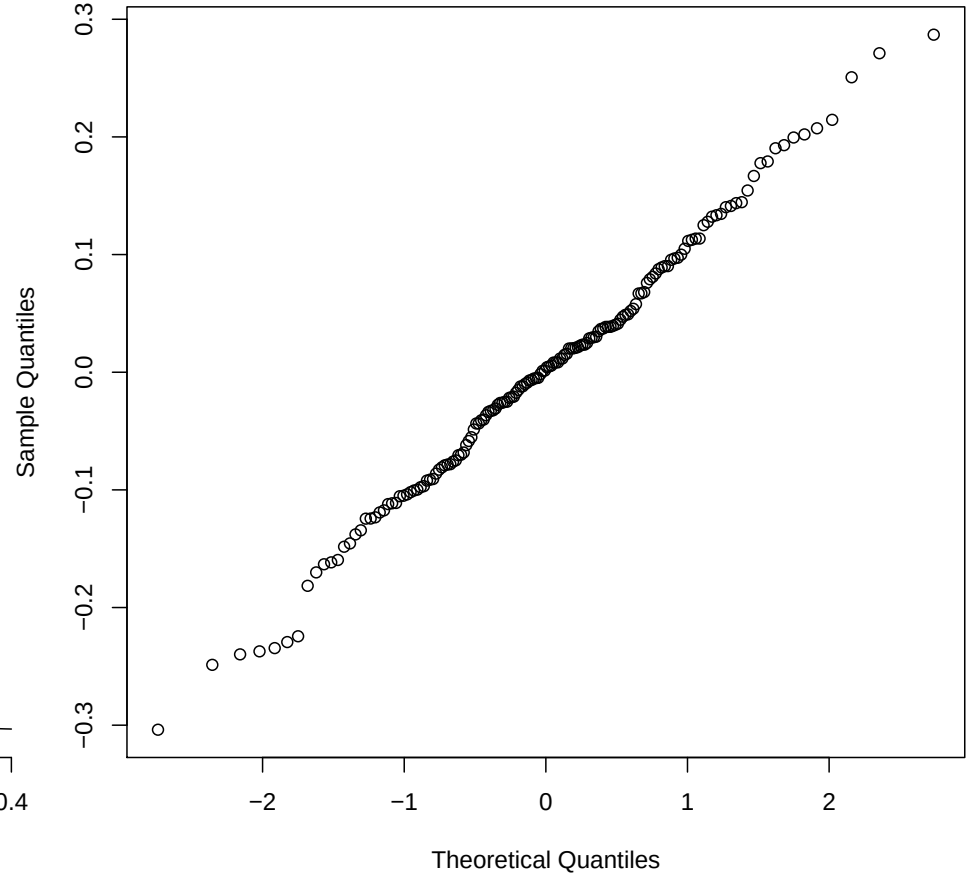


QQ normality plot

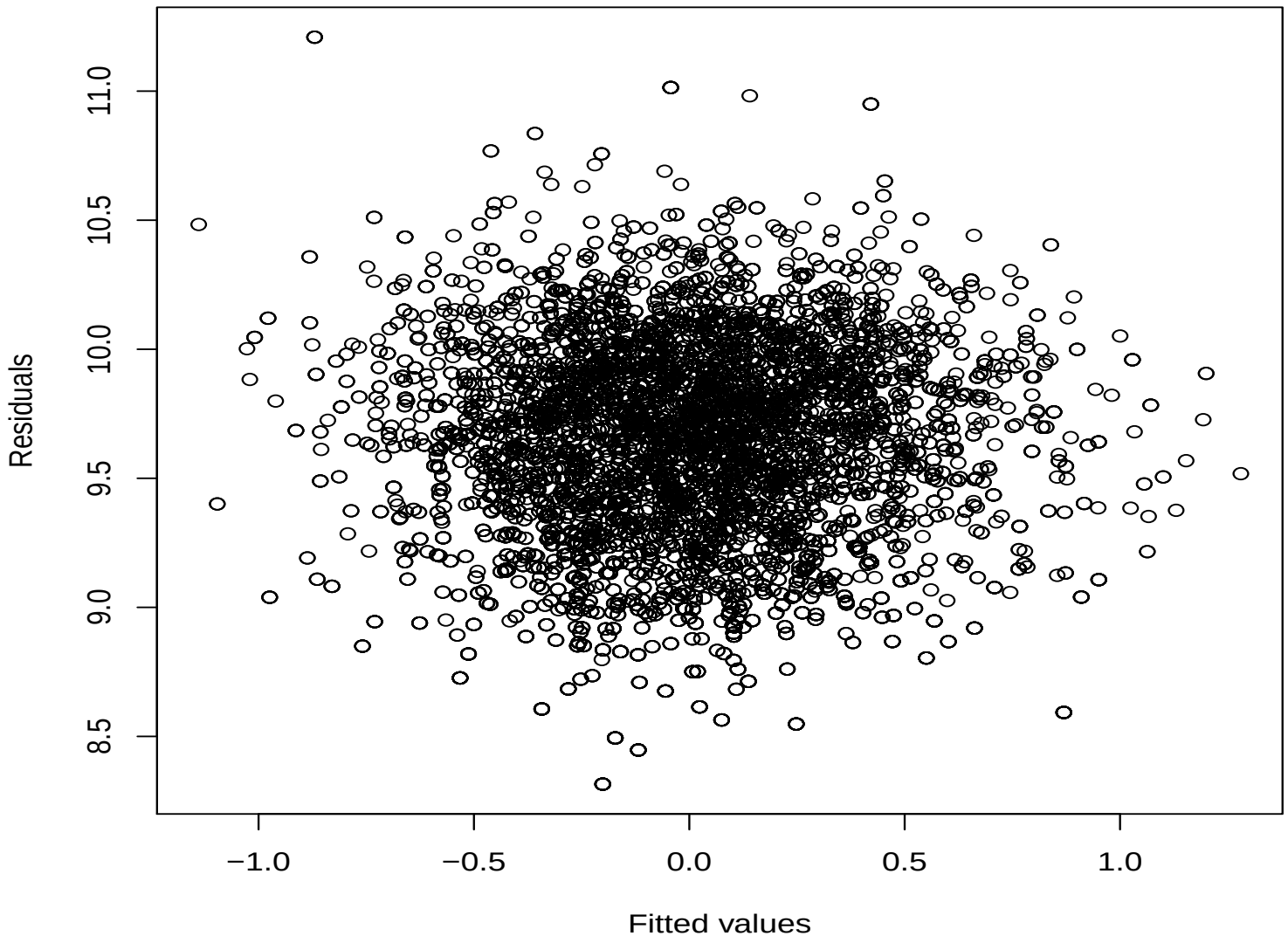


NORMALITY AREA EFFECTS





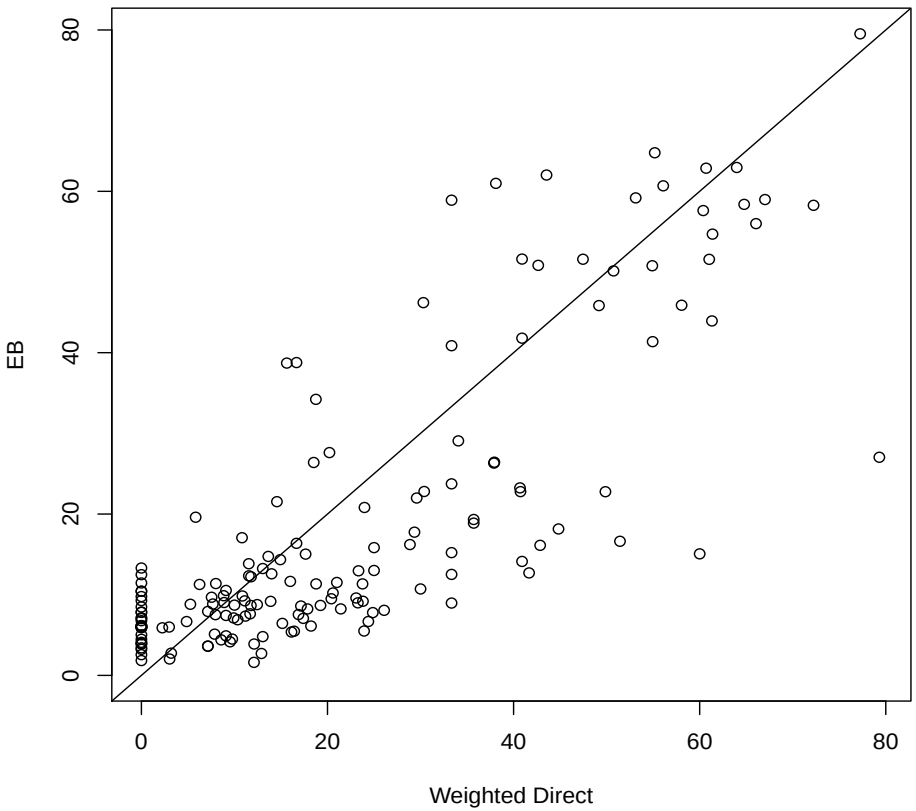
RESIDUALS vs. FITTED VALUES



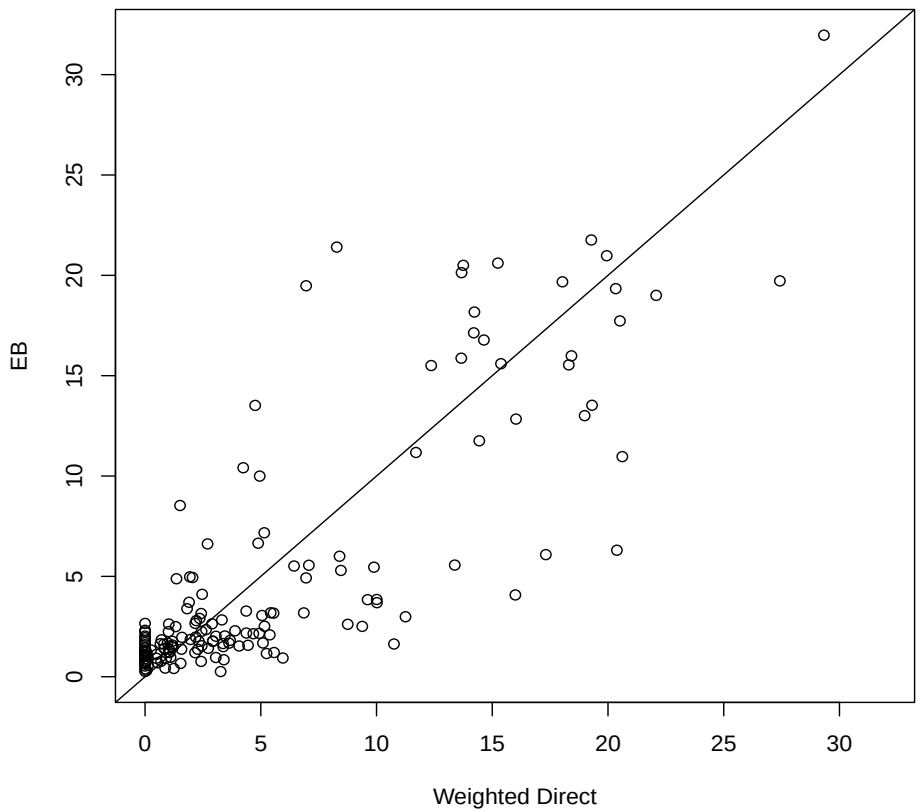
EB vs. DIRECT

✓ **No** visible **systematic bias** for EB!

Pov. Rate

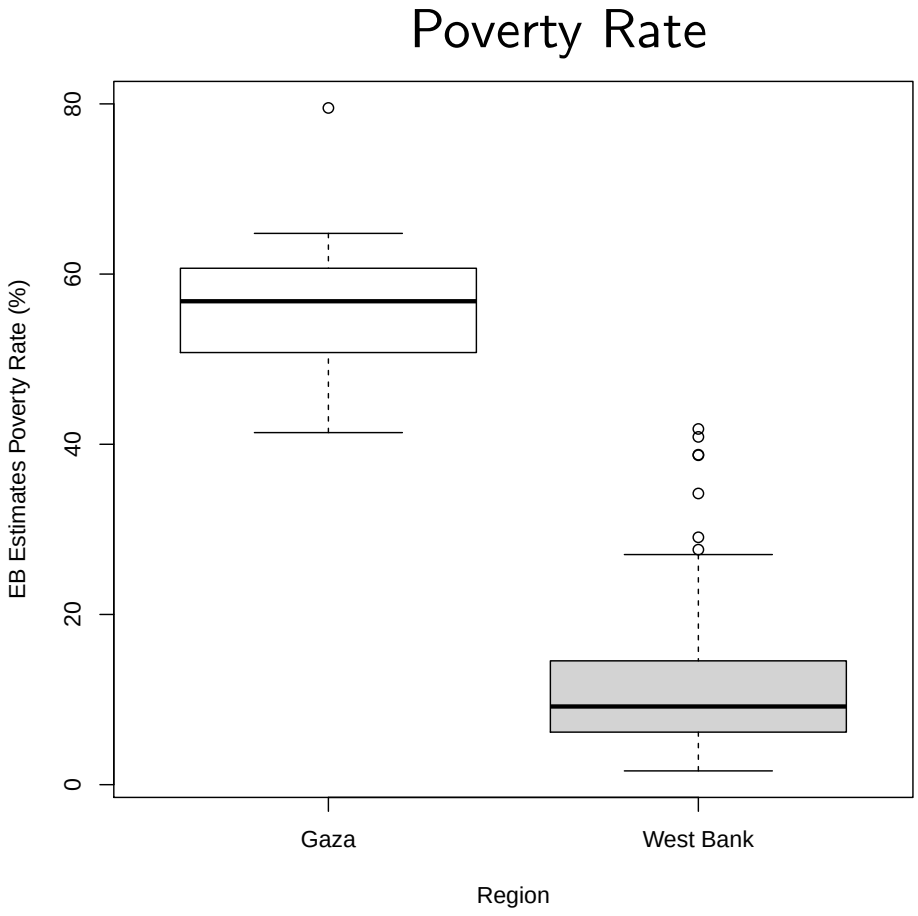


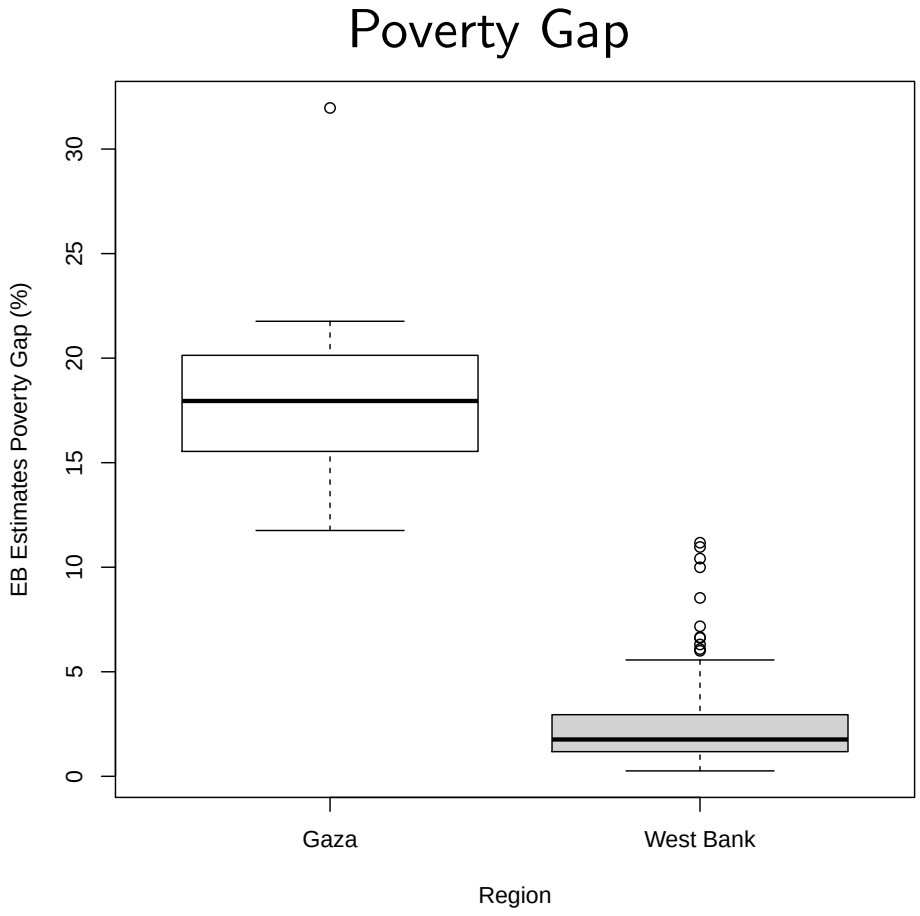
Pov. Gap



COMPARISON BY REGION

- ✓ Median Pov. Rate: Gaza **55 %**, West Bank: **8.3 %**
- ✓ Median Pov. Gap: Gaza **17.4 %**, West Bank: **1.5 %**

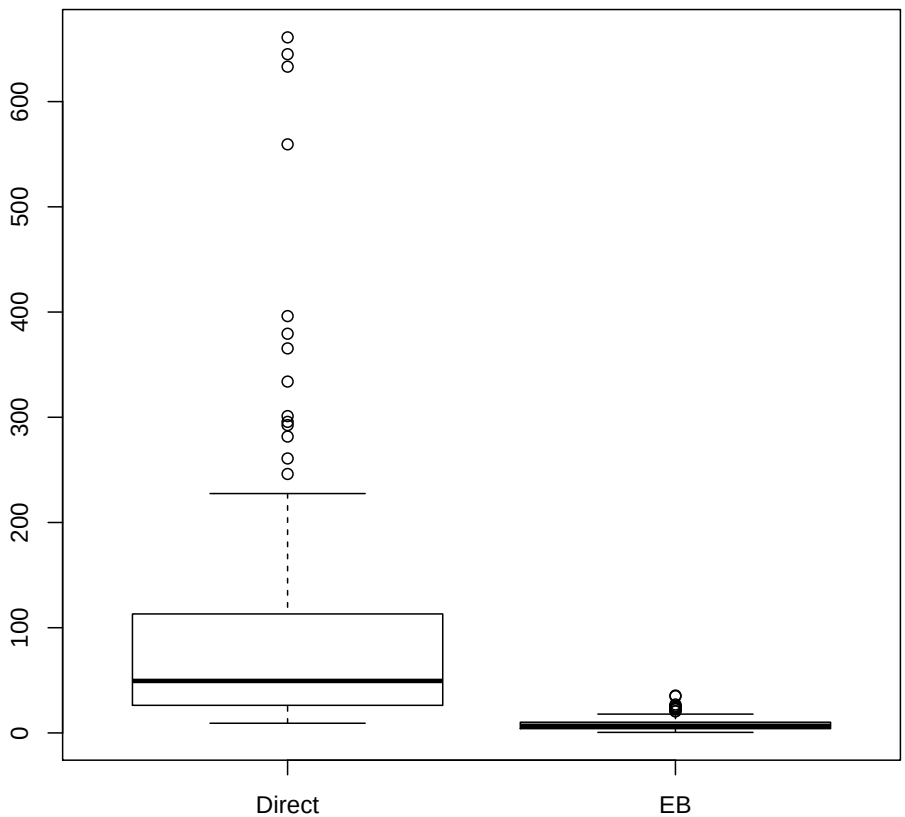




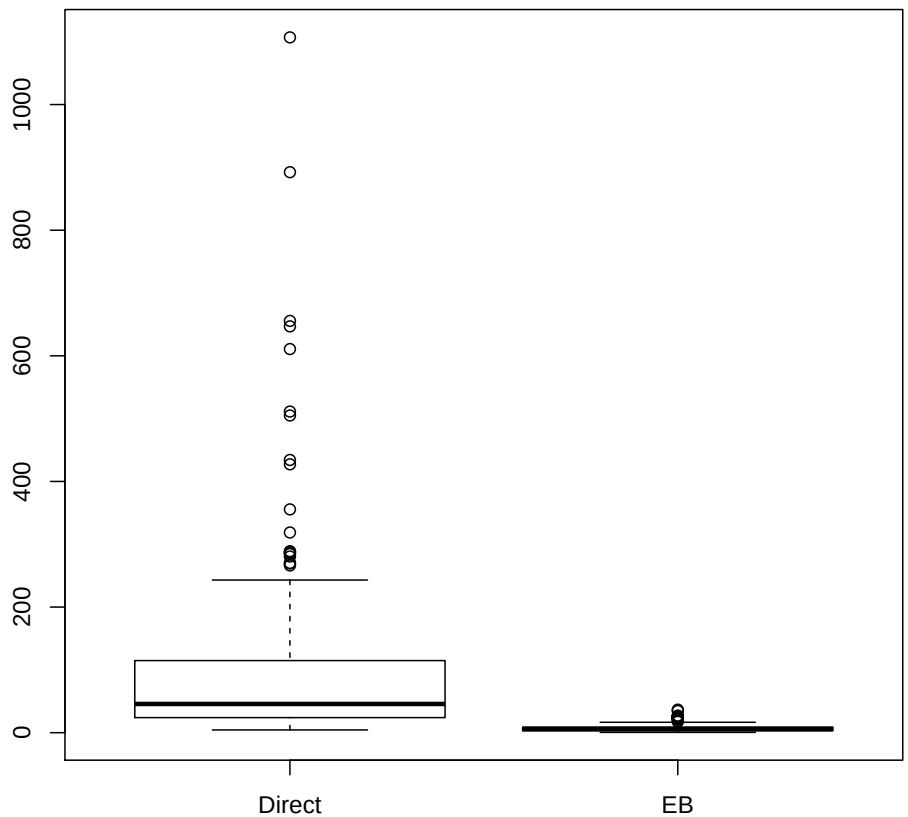
QUALITY EB vs. DIRECT: POV. RATE

- ✓ Median MSE Women: Direct **47**, EB: **6.7**
- ✓ Median MSE Men: Direct **45.8**, EB: **5.5**

MSE: Women

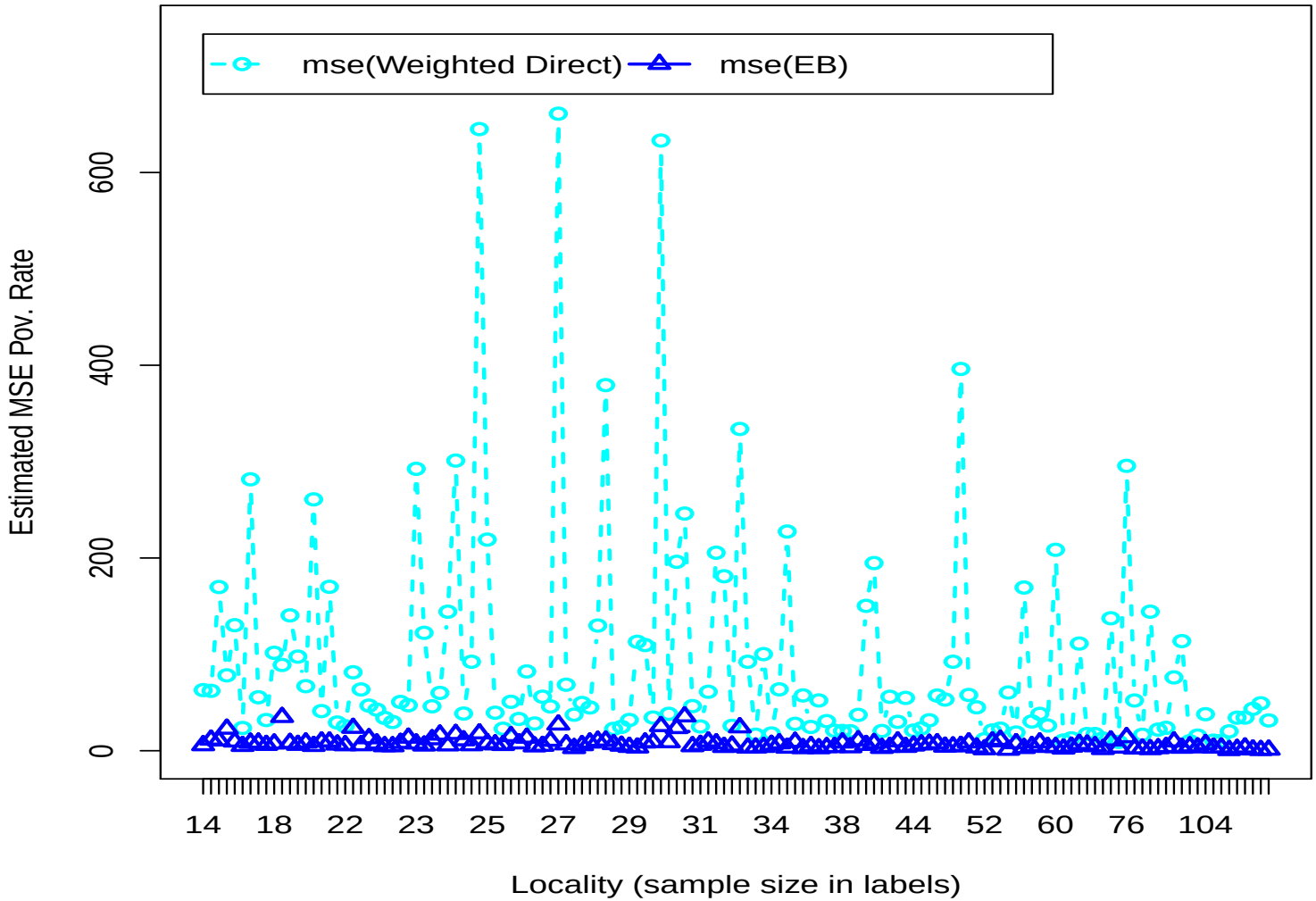


MSE: Men

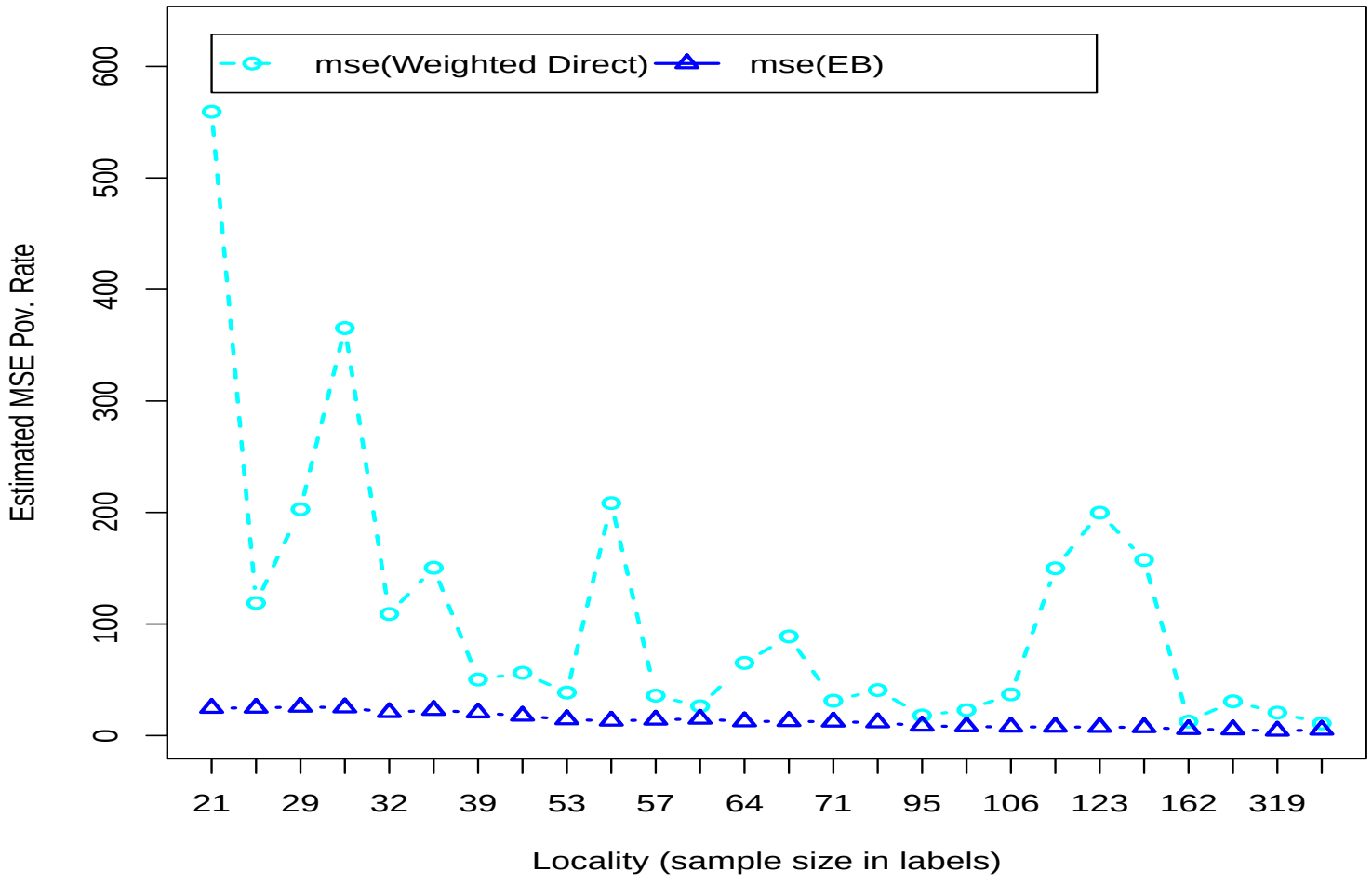


MSE EB vs. DIRECT POV. RATE: WEST BANK

✓ Reduction in **all** but one locality, **84 %** average MSE reduction!



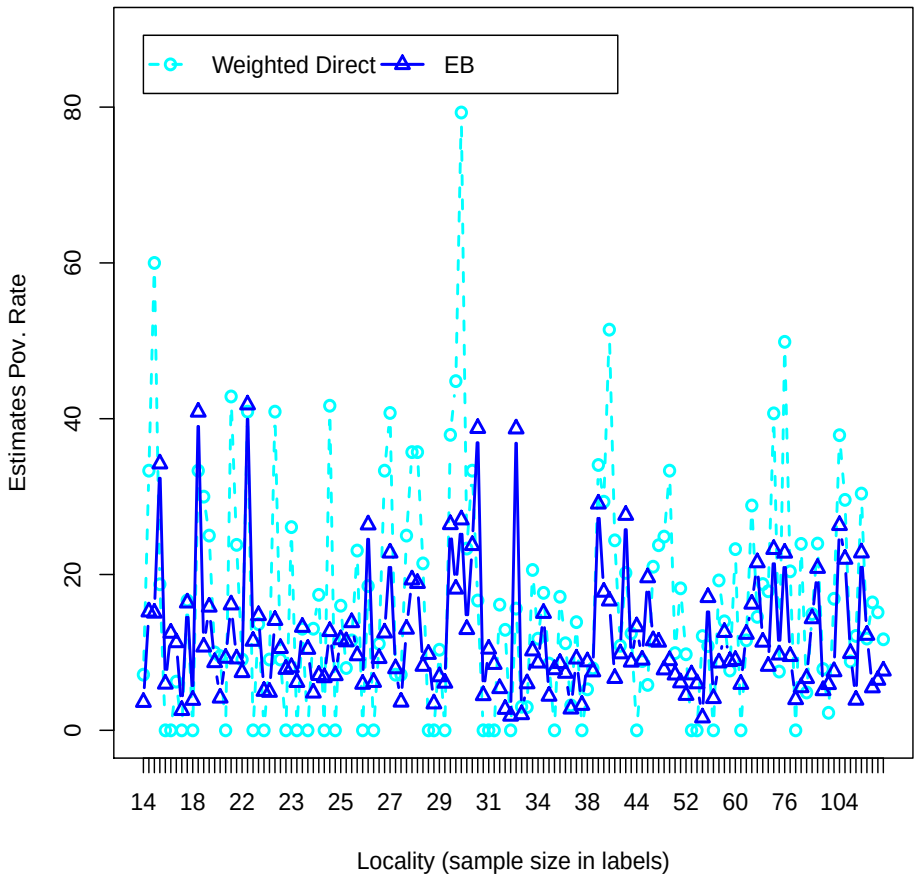
MSE EB vs. DIRECT POV. RATE: GAZA



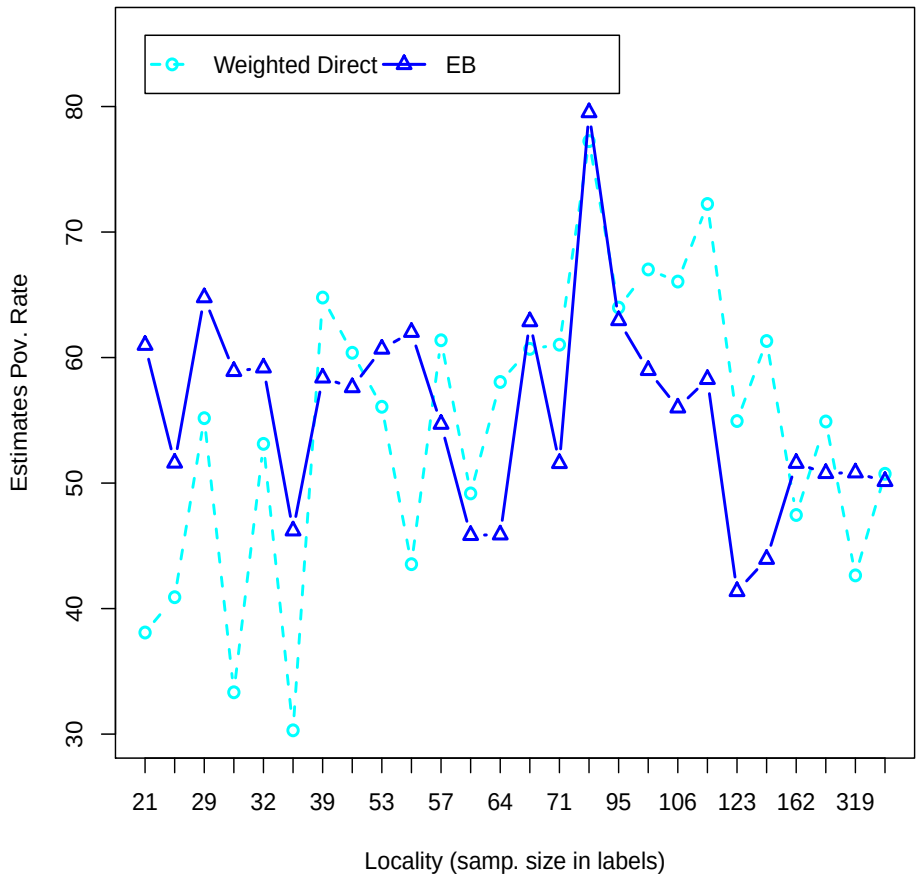
✓ **Great gains** also for Pov. **Gap** (not shown)!

ESTIMATED POV. RATE: WOMEN

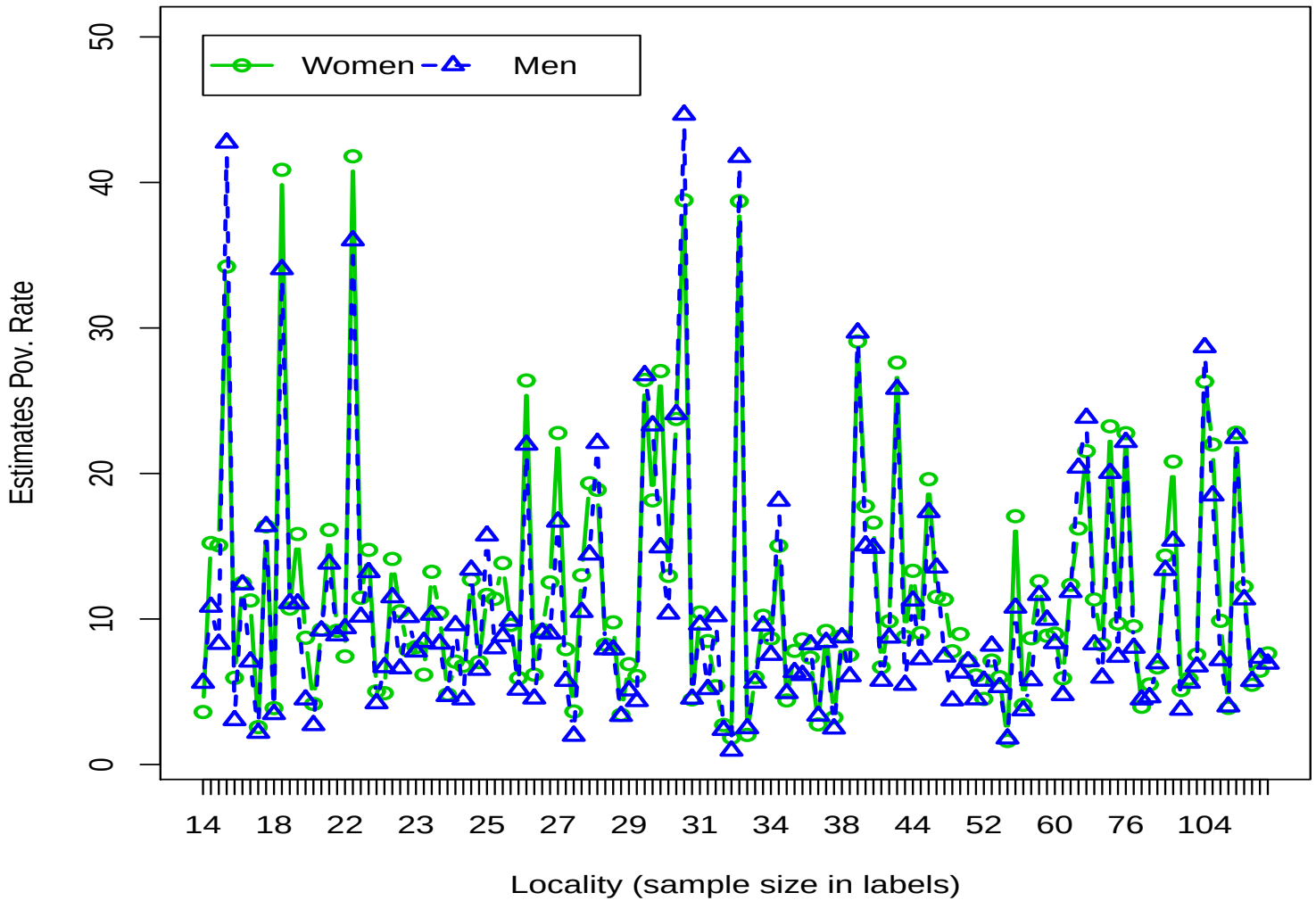
West Bank



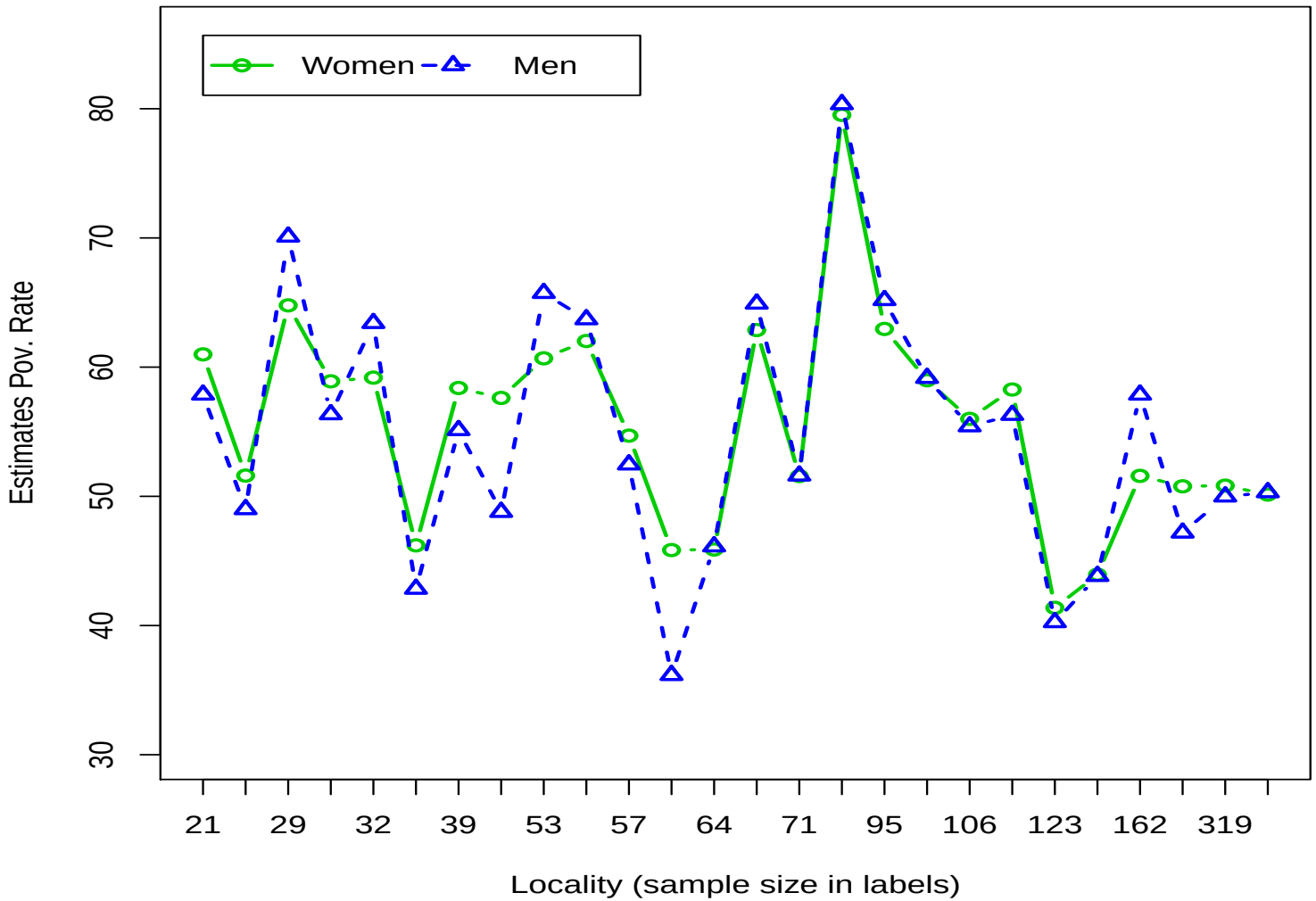
Gaza



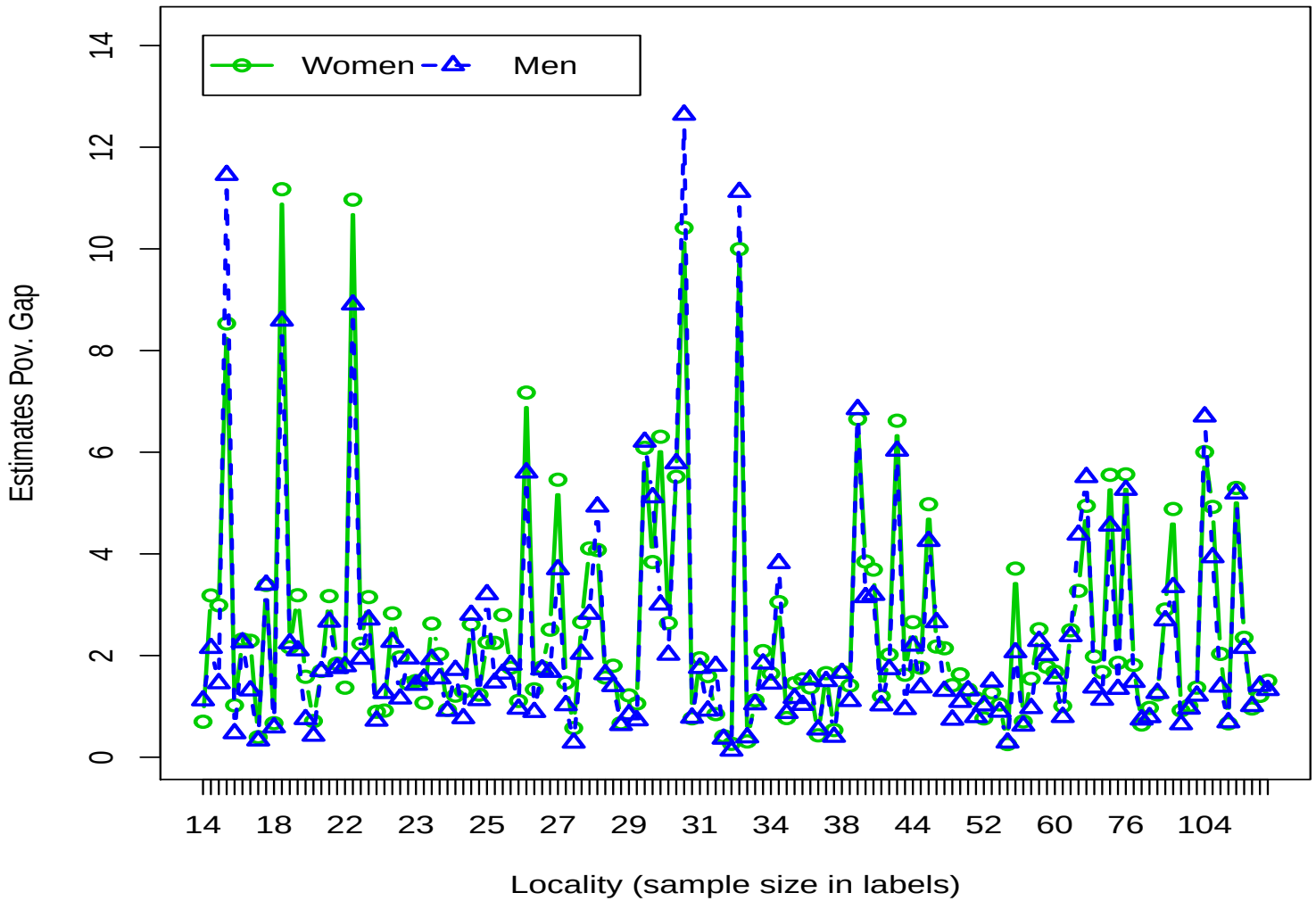
EB POV. RATE BY GENDER: WEST BANK



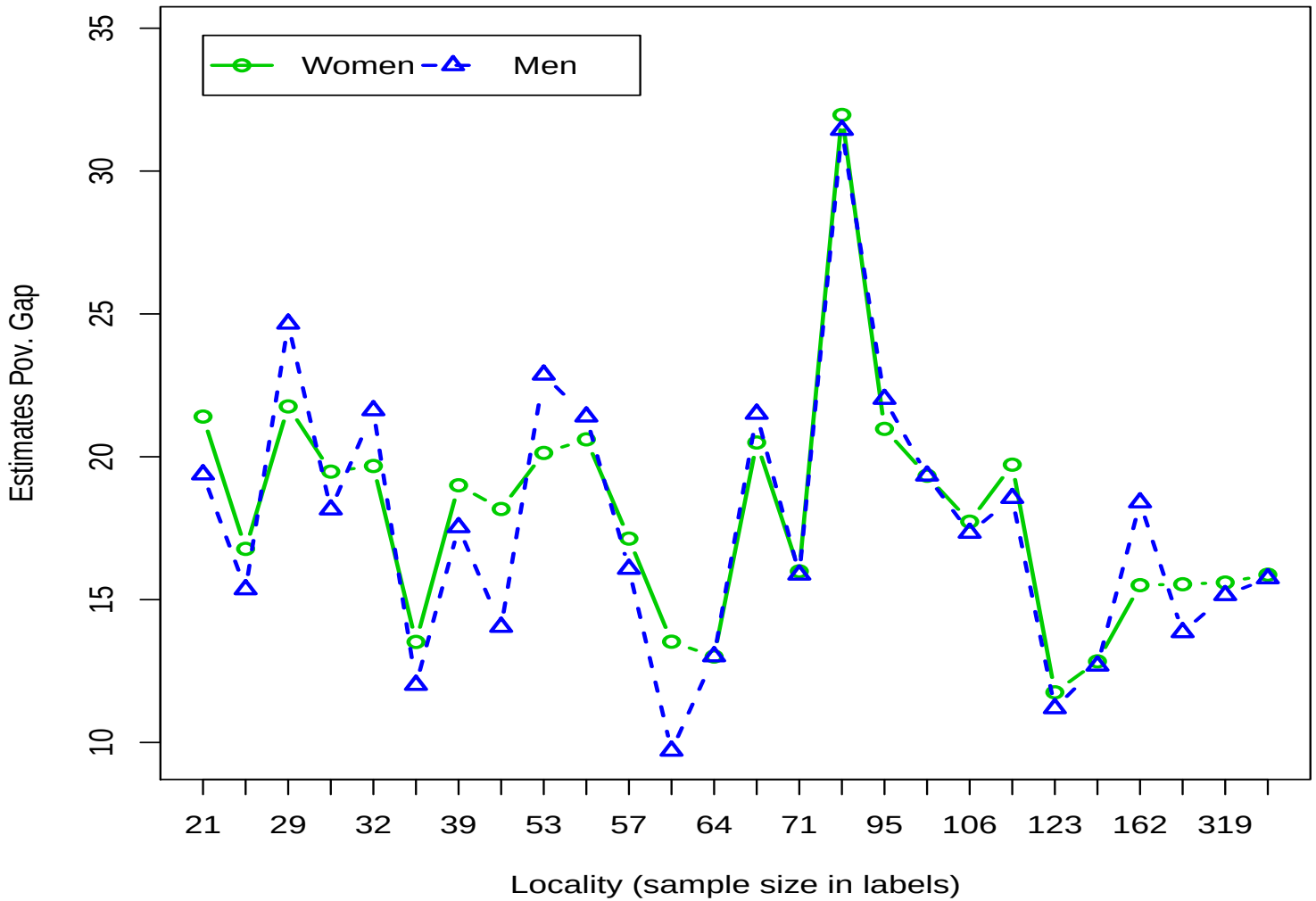
EB POV. RATE BY GENDER: GAZA



EB POV. GAP BY GENDER: WEST BANK



EB POV. GAP BY GENDER: GAZA



CONCLUSIONS

- The model **fits rather well** these data.
- We consider a model for the **individuals** instead of **households**. This allows estimation by gender.
- The unit level model allows to disaggregate estimates **at any desired level**. It allows to estimate **whatever indicator** that is function of expenditure.
- **Great efficiency gains** of EB with respect to direct estimators (over 82 % reduction in MSE for pov. rates and gaps).

CONCLUSIONS

- **Direct** estimates equal to **zero** for many localities (32 for Men, 29 for Women) and **highly unstable**.
- **EB** estimates **never zero** and much more stable. Perhaps some underestimation in few localities, model variations can be further explored.
- Gaza has **much larger** pov. rates and gaps. Perhaps using a different pov. line.
- No great differences between men and women, although women with slightly greater estimates for about 70 % of localities in West Bank.

- ✓ MANY THANKS TO UN-ESCWA AND PCBS FOR GREAT DATA PREPARATION!
- ✓ THANK YOU ALL FOR YOUR ATTENTION!