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Making Gravity Great Again

Will Martin

Selected presentation for the International Agricultural Trade Research Consortium's (IATRC's) 2020 Annual Meeting: Economic Implications of COVID-19, December 14-15, 2020, Virtual platform.

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Making Gravity Great Again

IATRC Annual Meeting

Will Martin

International Food Policy Research Institute

15 December 2020

Roadmap


- Importance of the Issue
- Econometric problems
- Approaches to estimation
- Monte Carlo estimates of bias

Importance of the question

- Gravity model fits data well– widely used for trade, investment, migration etc
- Many recent suggestions to replace traditional trade policy models
- Lack of agreement on the best estimators
 - Wide differences between results from different estimators

Econometric problems

Econometric challenges

- Limited-Dependent Variable Bias
 - Large shares of trade, investment, migration data are zeros
 - 40% in aggregate trade flows, higher for disaggregate data
 - Creates bias due to non-zero errors
- Combination of nonlinearity & heteroscedasticity
 - Correlation between errors & explanatory variables  bias
 - Inefficient rather than biased with linear models
 - Estimating in logs gives linearity, but then the zeros truncated
- Heteroscedasticity gives different bias with limited-dependent estimators
 - Whether linear or non-linear
- Some zero observations are not zero, just missing

Eaton-Kortum Tobit Model

$$y_i^* = f(x_i, \beta) + u_i$$

$$y_i = y_i^* \quad \text{if } y_i^* > \mathbf{Y} \text{ or}$$
$$y_i = 0 \quad \text{if } y_i^* \leq \mathbf{Y}$$



Threshold

- Where y is a latent variable, x an explanatory variable, \mathbf{Y} a minimum threshold, and u an error term, that differs between observations

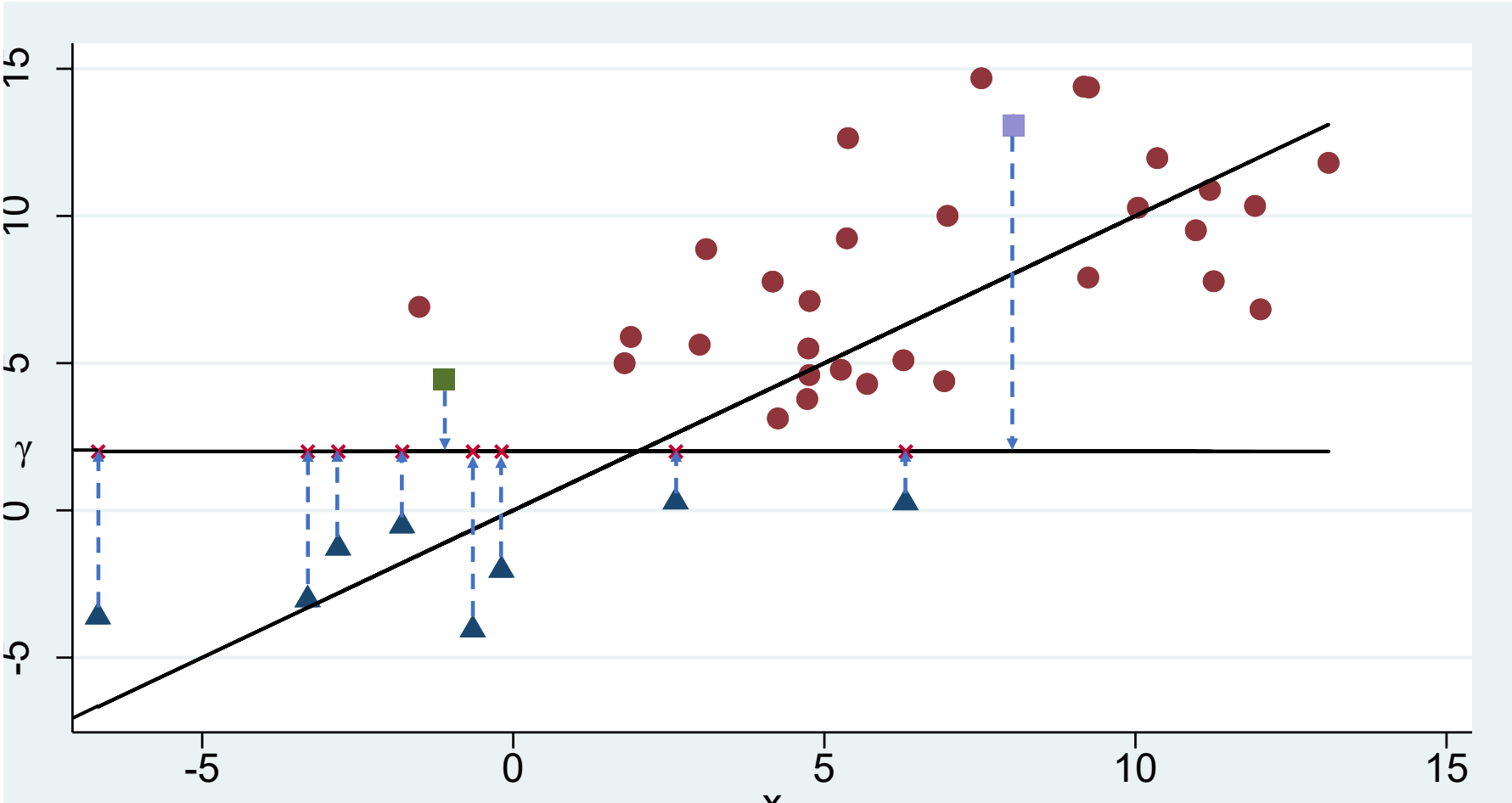
Likelihood function for this model

- $L(\beta, \sigma) = \prod_{i=1}^{n_0} \Phi\left(\frac{y-f(x_i, \beta)}{\sigma_i}\right) \prod_{i=n_0+1}^n \frac{1}{\sigma_i} \phi\left(\frac{y-f(x_i, \beta)}{\sigma_i}\right)$
- ϕ is the density function for non-limit observations
- Φ is the distribution function for limit observations

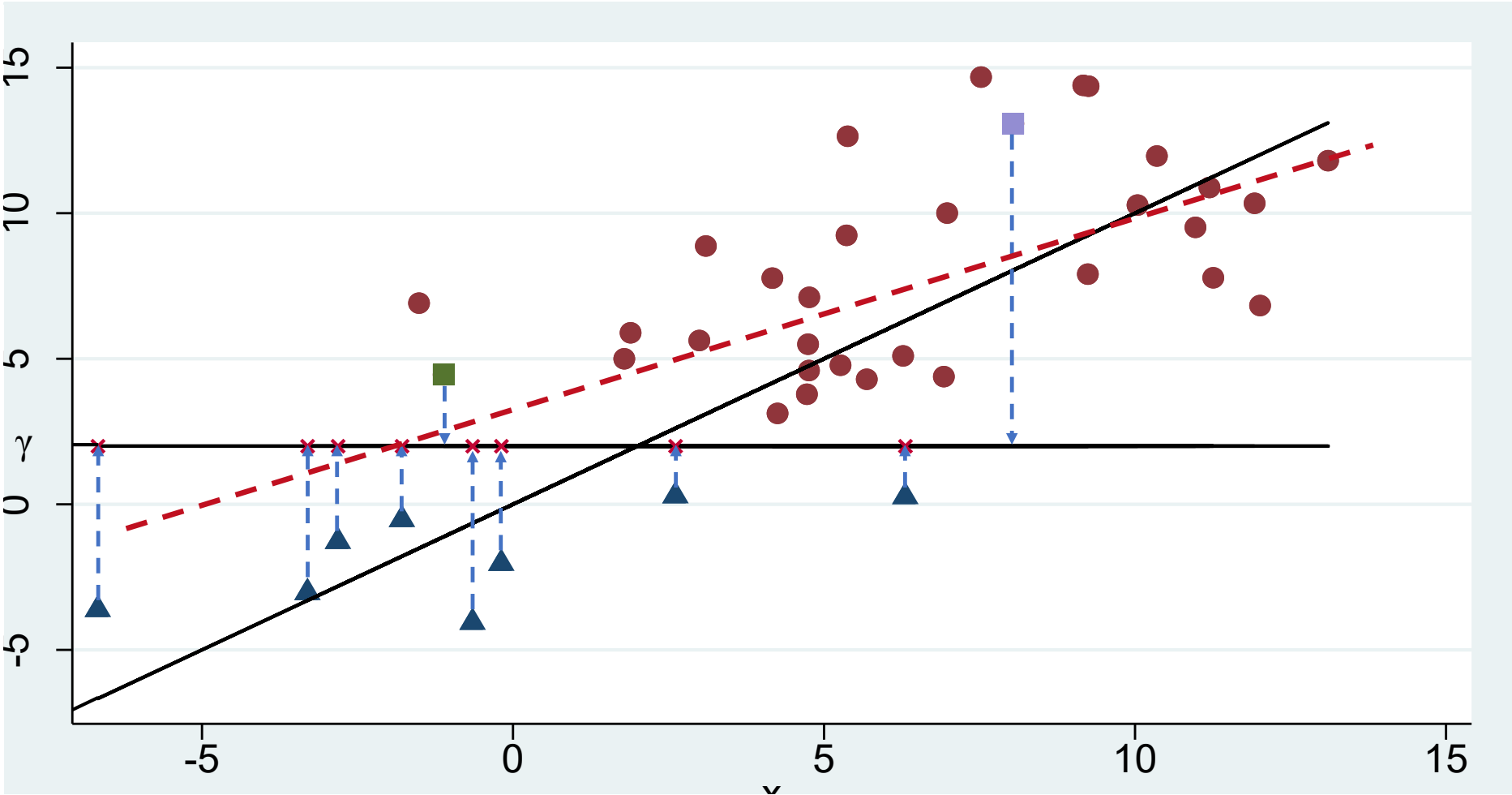
Eaton-Kortum/Carson-Sun Threshold Model

- Threshold often taken to be zero
 - But the lowest profitable value of trade $\gamma > 0$
- Carson-Sun examine automobiles
 - Smallest new vehicle purchase the cheapest available car
- Eaton-Kortum propose using the lowest observed import to country
 - Carson-Sun show estimator is super-consistent wrt γ
- $\gamma > 0$ eliminates the zero problem in log models

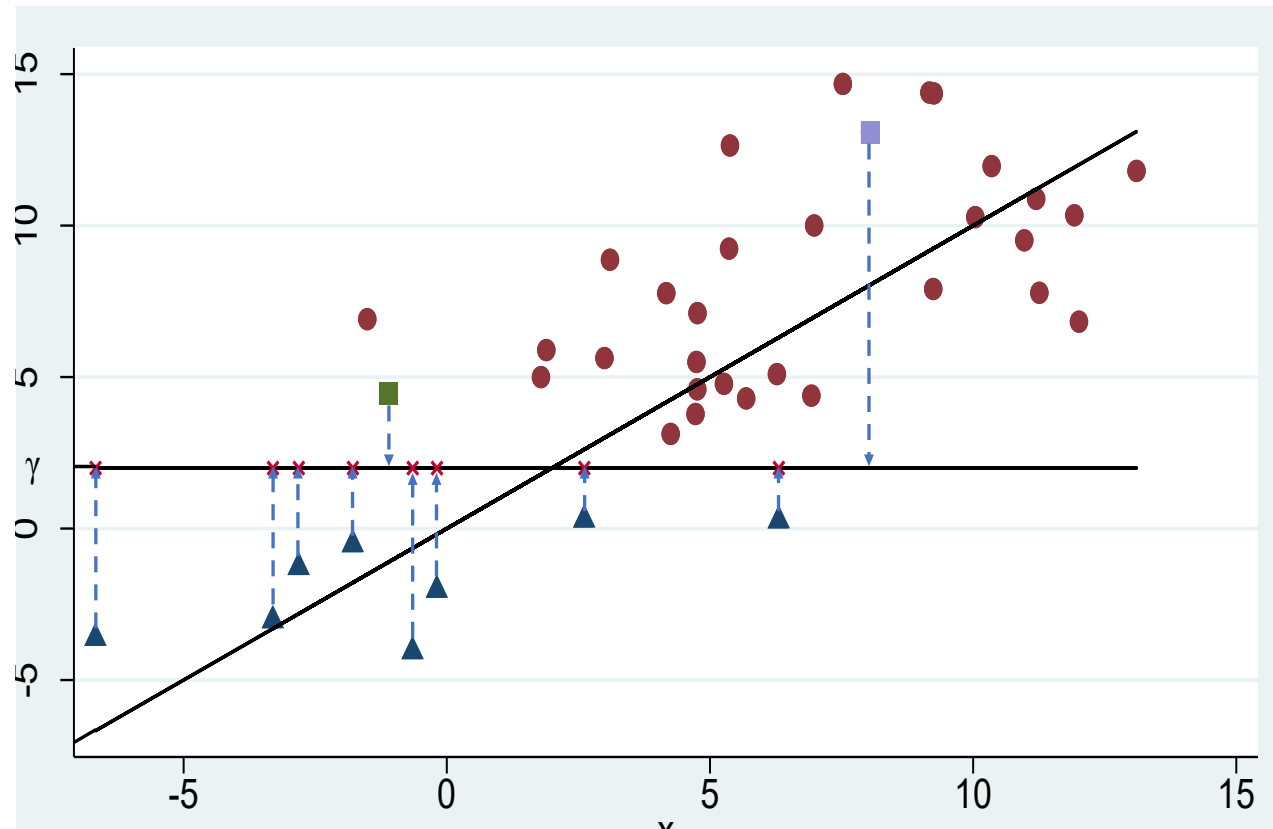
x Values represented by Distn fn, ●s by Density



Limited-Dependent: Downward Bias with OLS



Missing Data Recorded as Zeros



- Biased up if missing data small
- Biased down if missing data large

Estimation

Consider six estimators

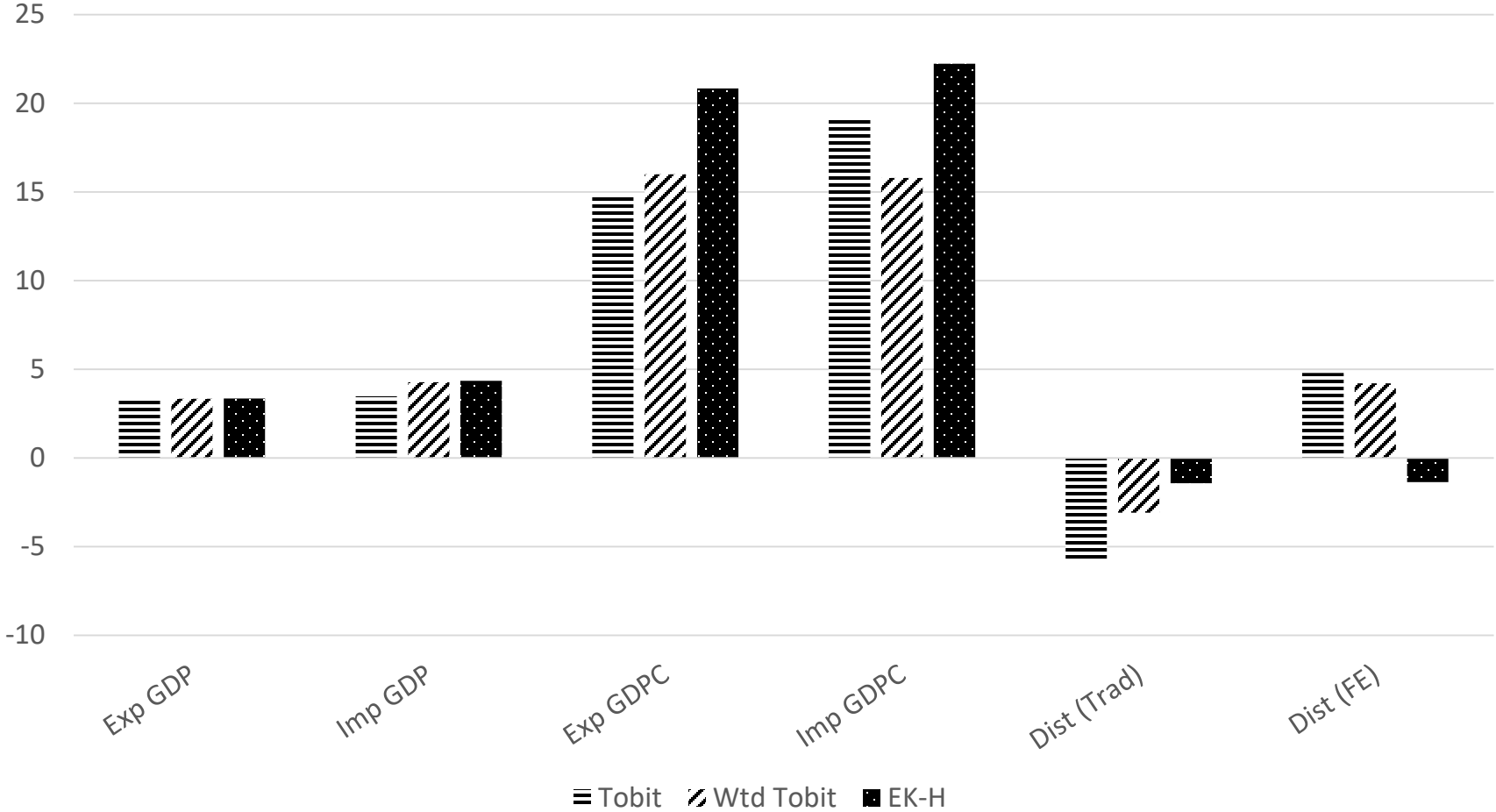
- OLS in logs
 - Traditional model– zeros truncated
- PPML
- Generalized Least Squares (for heteroscedasticity)
- Threshold Tobit
- Weighted Tobit
- Eaton-Kortum with heteroscedasticity, EK-H

Dataset

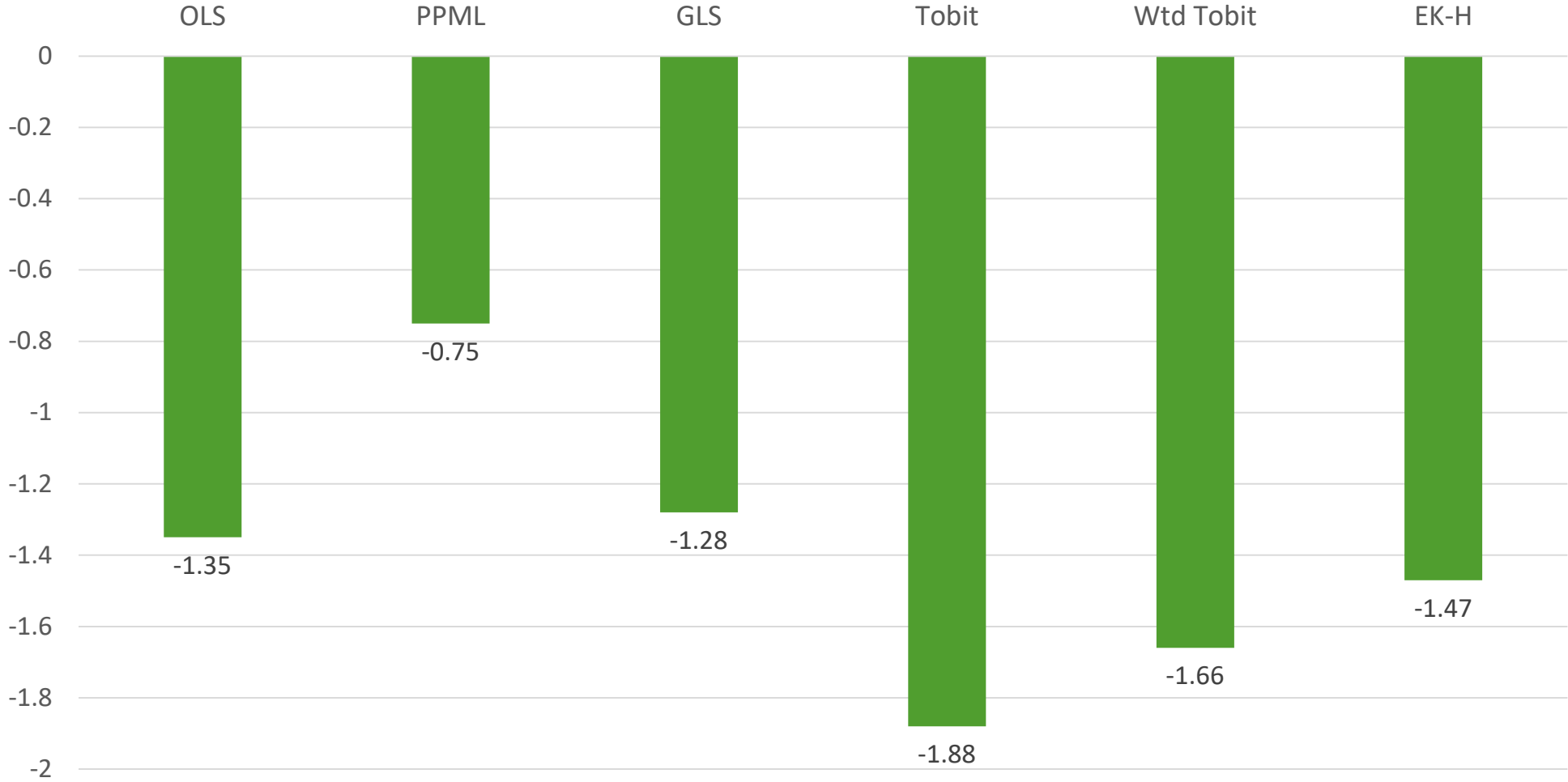
- 136*136 cross-sectional trade matrix by Feenstra, Lipsey & Bowen
 - Used by Santos Silva & Tenreyro & many other studies
 - 48% zeros
- 46 of 136 economies did not report trade to COMTRADE for 1992
 - 2059 of the potential 2070 trade flows between them were zero
 - Clearly no attempt made to impute these data
 - Safer to exclude them
- Resulting 16290 cross-sectional observations with 41% zeros

Effect of adding the missing data as zeros

– upward bias



Huge Differences in Estimates: Dist. in FE Gravity



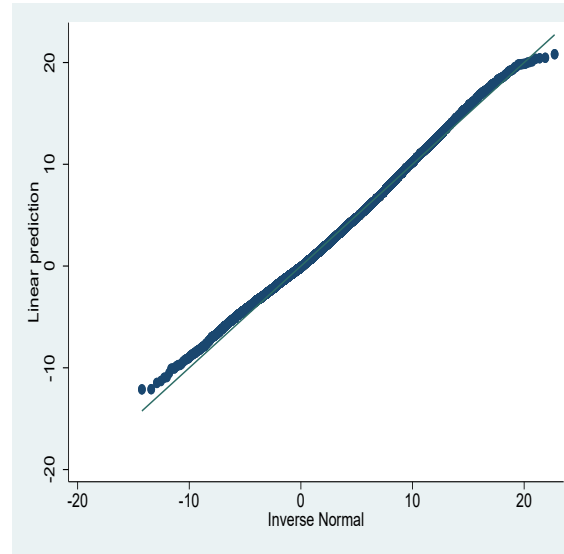
Monte Carlo Analysis

Monte Carlo Analysis misleading unless parameters well-chosen. What matters?

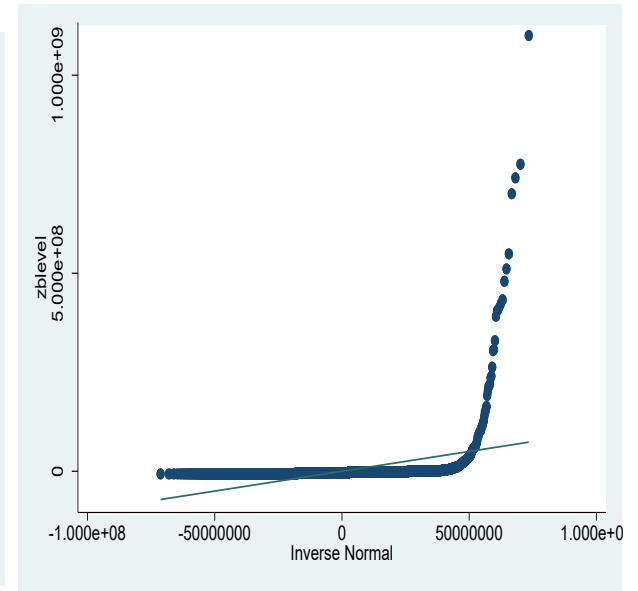
1. The *distribution of predicted* outcomes, including
 - (i) Their distribution & whether normal or log-normal,
 - (ii) The mean & variance of this distribution
2. *Distribution of residuals* around expected trade outcomes, incl:
 - (i) Their distribution,
 - (ii) Their standard deviation at any point, σ_i , and
 - (iii) The pattern of heteroscedasticity
3. The fraction of *observations at the threshold*

QQ plots 4 Normality

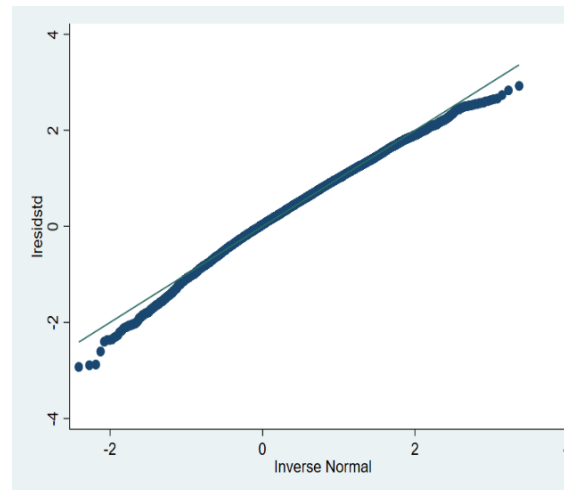
1. Predicted Values, logs



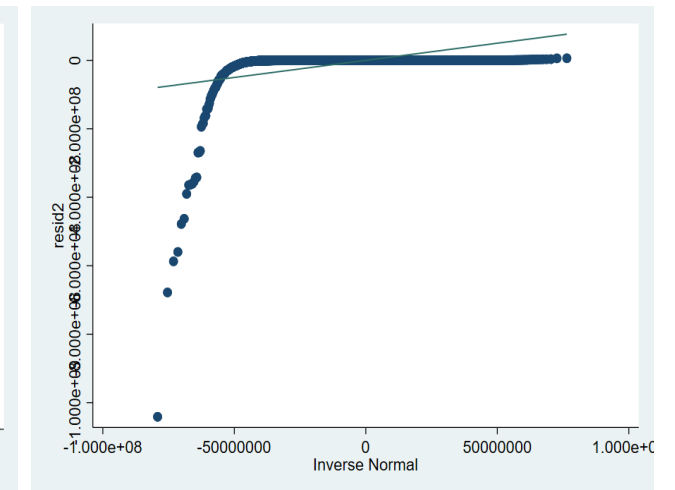
2. Predicted Values, Levels



3. Residuals, logs



4. Residuals, levels



Parameters from 2 candidate models: PPML & EK-H

- *Test model:* $y = 1.x + u$
- $x \sim N(4.2, 4.85)$ for EK-H Data Gen Process
- $x \sim N(8.2, 2.8)$ for PPML DGP
- $\sigma_i^2 = e^{(a+by_i)}$ where $a = 2.7$ & $b = -0.115$
- Samples of 10,000 repeated 1000 times

Monte Carlo Results

	EK-H Parameters		PPML Parameters	
	$\hat{\beta}$	Std Error	$\hat{\beta}$	Std Error
OLS	0.62	0.01	0.52	0.01
PPML	0.87	0.13	0.78	0.11
Tobit	0.89	0.01	0.90	0.01
Weighted Tobit	0.92	0.03	0.85	0.02
EK-H	0.999	0.01	1.000	0.001

Conclusions

- Need good estimates from the gravity model
 - Potentially serious biases from
 - (i) limited dependent variables
 - (ii) heteroscedasticity & nonlinearity, &
 - (iii) missing values mapped to zeros
- Estimates vary enormously between widely-used estimators
 - Need Monte Carlo analyses to distinguish against known parameters
 - Must use distributions in the relevant range
- EK-H estimator allowing for heteroscedasticity & limited-dependent vbls unbiased
 - Traditional OLS very seriously biased
 - PPML biased around 20%, Tobit & Hetero-Wtd Tobit a little better