"Rage against the Machines: Labor-Saving Technology and Unrest in Industrializing England" by Caprettini and Voth, AER, 2020

Replication and Simulations

Mateo Bortoli, Elie Malhaire

ENS de Lyon

Section 1

Replication

Context

The paper analyse the "Captain Swing" riots in 1830s England to study the introduction of new technologies (threshold machines) on political outcomes (riots).

- Threshing machines invented in 1786, spread from 1810.
- Replaced rural laborers, reducing their income.
- Coupled with land enclosure reducing peasants' land access.

Riots:

- Began in Kent (1830), spread to 45 counties.
- 3,000 riots; 514 machines attacked; 252 sentenced to death.

Data Sources

Threshing machines:

- Regional newspapers (1800-1830): 549 machines in 466 parishes.
- General Views of Agriculture reports.

Unrest:

- Swing Riots data (Family and Community Historical Research Society).
- British Newspaper Archive: 610 arson incidents, 69 machine attacks (1758–1829).

Other factors:

- Soil composition (Geological Map of Great Britain).
- Population data (censuses from 1801–1831).

Regression Model

Model:

$$\text{Riots}_p = \beta_0 + \beta_1 \text{Machines}_p + \beta_2 \text{density}_{p1801} + \beta_X X_p + \theta_r + \epsilon_p$$

Variables:

- Riots_p: Number of riots in parish p.
- Machines_p: Number of threshing machines introduced.
- density_{p1801}: Population density (1801).
- X_p: Other explanatory variables.
- θ_r: Region fixed effects.

Regression Results: OLS

	Estimate	Std. Error	Significance
Intercept	1.60027	0.12530	***
thresh	0.38855	0.03795	***
log_density	0.10061	0.01307	***
agri_share	-0.06483	0.04433	
log_sex_ratio	-0.18142	0.06068	**

Table: OLS Results

Regression Results: IV

	Estimate	Std. Error	Significance
Intercept	1.47285	0.24405	***
thresh	6.36131	1.68165	***
log_density	0.01049	0.03480	
agri_share	0.02418	0.08782	

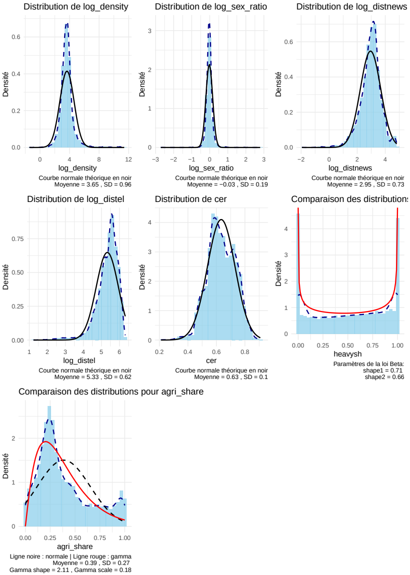
Table: IV Results

Instrumental Variable: Heavy soils are negatively correlated with the introduction of threshold machines (and are only correlated to the riots through that channel).

Section 2

First Simulations

First Simulation: OLS Model



First Simulation: OLS Model

Using the shape of the data provided by the publications authors, we simulate the key variables of the original model.

We then use our two theoretical true effects:

- the one from the OLS of the article $\beta_{\text{thresh\_OLS}} = 0.35306$;
- the one from the 2SLS $\beta_{\text{thresh\_IV}} = 6.557$.

From these data, we simulate our dependent variable (Riots) in a dataset of 5000 observations and we run this operation 100 times. These bases can then serve as a dataset for our regressions.

Distributions of the simulated coefficients

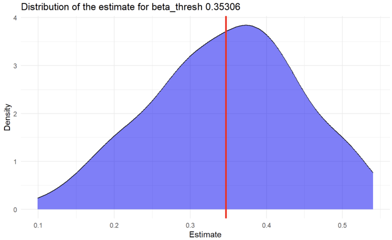


Figure: Distribution of β simulated via $\beta_{\text{thresh\_OLS}}$

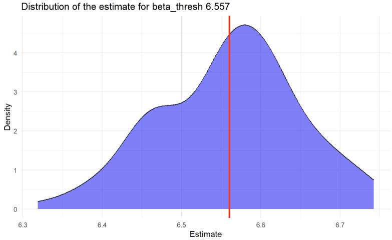


Figure: Distribution of β simulated via $\beta_{\text{thresh\_IV}}$

Results

Table: Résultats pour $\beta_{\text{thresh}} = 0.35306$

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Estimates	0.1125	0.2729	0.3446	0.3478	0.4155	0.6076
P-value	0.0000	0.00002187	0.0004284	0.01057	0.005626	0.2291

Table: Résultats pour $\beta_{\text{thresh}} = 6.557$

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Estimate	6.308	6.485	6.551	6.550	6.610	6.755
P-value	0	0	0	0	0	0

Results

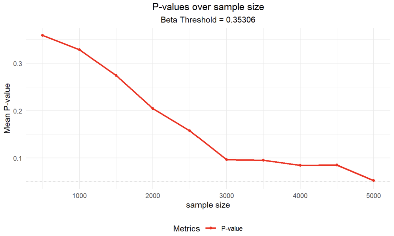
From the simulation over $\beta_{\text{thresh\_OLS}}$, we find significant effects, and consistant with the paper.

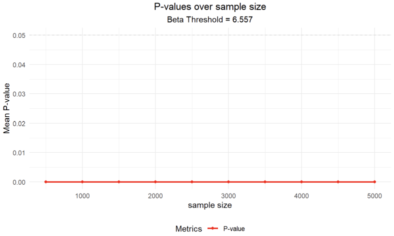
From the simulation over $\beta_{\text{thresh\_IV}}$ the coefficients are very stable and the mean is also consistent with the true effect.
However, the P-value are all at zero for the simulation over $\beta_{\text{thresh\_IV}}$. As the statistical power is an increasing function of precision and effect size, we can think that the use of the beta of the IV in our simulation creates exaggeration in the estimation of our coefficients.

Test the p-values

In order to analyze our p-values in more detail, we then make our DGP more complex:

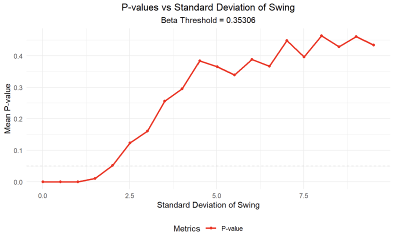
- by varying the sample size:

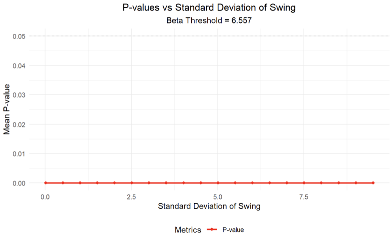




Test the p-values

- by varying the standard deviations used for the creation by simulation of the SWING variable (Riots):





Test the p-values

For the simulation based on the true effect of the OLS, the sample size must be at least 3000 observations and that the standard deviation applied to our dependent variable must not exceed 2.2 in order to reject the null hypothesis.

Concerning the simulation based on the true effect of the IV, the original coefficient is so large that neither the sample size nor the standard deviation influences the p-value, which remains constantly zero.

It is then appropriate to investigate whether or not we are facing exaggeration.

Section 3

Second Simulations

Complexify the GDP

- **Instrument (heavysh):** Continuous, Beta-distributed.
- **Treatment (thresh):** Binary variable
- **Outcome (SWING):** Continuous and positive

$$\text{SWING} = \exp\left(\frac{\beta_0 + \beta_{\text{thresh}} \cdot \text{thresh} + \beta_{\mathbf{X}} \cdot \mathbf{X} + \text{error}_2}{4}\right)$$

- **Covariates (X):** Vector of observed control variables.

First Stage: Probit Regression

- **Objective:** Model the probability that the treatment variable (**thresh**) equals 1 as a function of the instrument (**heavysh**) and covariates.
- **Probit Model:**

$$P(\text{thresh} = 1 | \text{heavysh}, \mathbf{X}) = \Phi\left(\beta_0 + \beta_{\text{heavysh}} \cdot \text{heavysh} + \beta_{\mathbf{X}} \cdot \mathbf{X}\right)$$

  - $\Phi(\cdot)$: The cumulative normal distribution function, mapping the linear predictor to probabilities between 0 and 1.
  - $\mathbf{X}$: Vector of covariates.

First Stage: Probit Regression

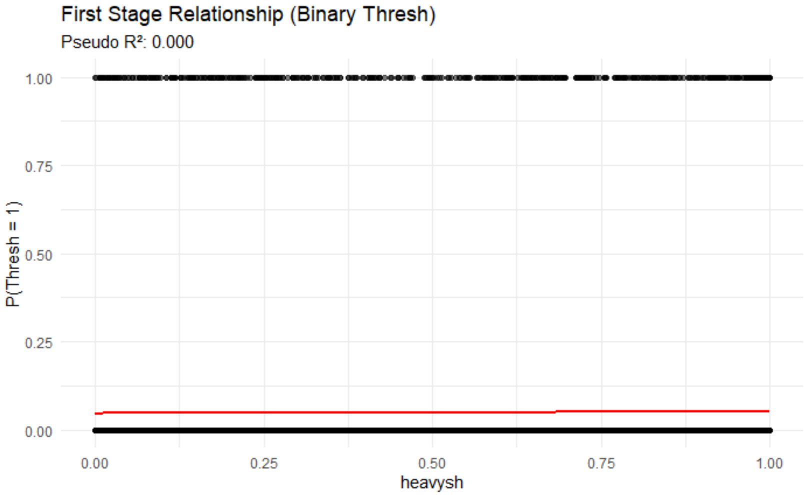


Figure: Quality of soil is a poor instrument for estimating threshers

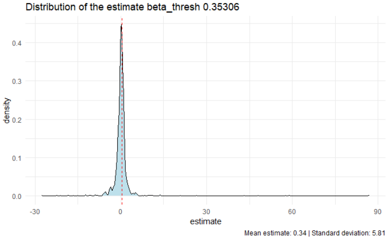
Second Stage: IV Regression (2SLS)

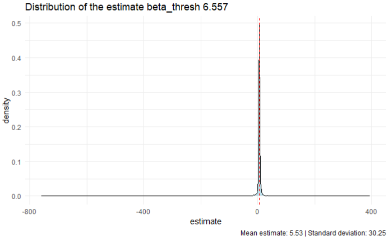
- **Objective:** Estimate the causal effect of **thresh** on **SWING** while addressing endogeneity.
- **Regression Model:**

$$\text{SWING} = \beta_0 + \beta_{\text{thresh}} \cdot \widehat{\text{thresh}} + \beta_{\mathbf{X}} \cdot \mathbf{X} + \epsilon$$

  - $\widehat{\text{thresh}}$: Predicted values of **thresh** obtained from the first-stage Probit regression.
  - $\mathbf{X}$: Covariate vector controlling for observed heterogeneity.

Results


Distribution of the estimate beta_thresh 0.35306
density
0.4
0.3
0.2
0.1
0.0
-30
0
30
60
90
estimate
Mean estimate: 0.34 | Standard deviation: 5.81


Distribution of the estimate beta_thresh 6.557
density
0.5
0.4
0.3
0.2
0.1
0.0
-800
-400
0
400
estimate
Mean estimate: 5.53 | Standard deviation: 30.25

Results: Simulation Insights

Key Observations from Simulated Data:

Main Finding

Due to the weakness of the instrument, the simulated data fail to recover the true causal effect.

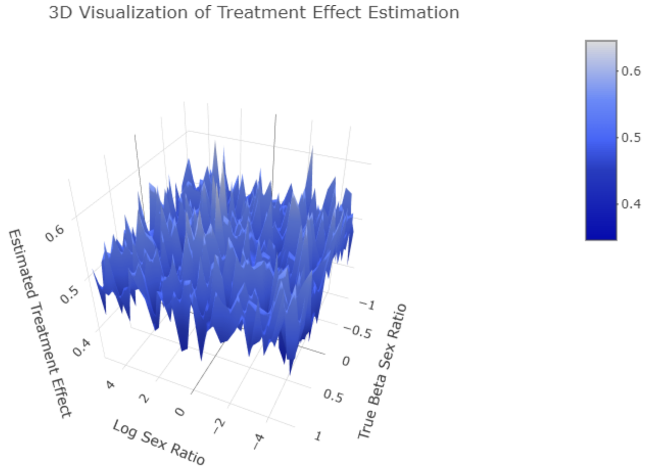
- **Very Low Statistical Power:** Approximately **5%**.
- **Very High Type S Error:** Approximately **50%**.
- **Very High Type M Error:** Approximately **150%**.

These results emphasize the challenges of weak instruments in causal inference.

Modeling Gender Ratio and Protests

- Vary the gender ratio by adjusting the mean of a binomial distribution (from -5 to 5), ensuring a range from almost 100% female to almost 100% male.
- True gender effect is varied between -1 and 1 to explore sensitivity in the estimated coefficients.

Results


3D Visualization of Treatment Effect Estimation
Estimated Treatment Effect
0.6
0.5
0.4
Log Sex Ratio
4
2
0
−2
−4
True Beta Sex Ratio
−1
−0.5
0
0.5
1
0.6
0.5
0.4