

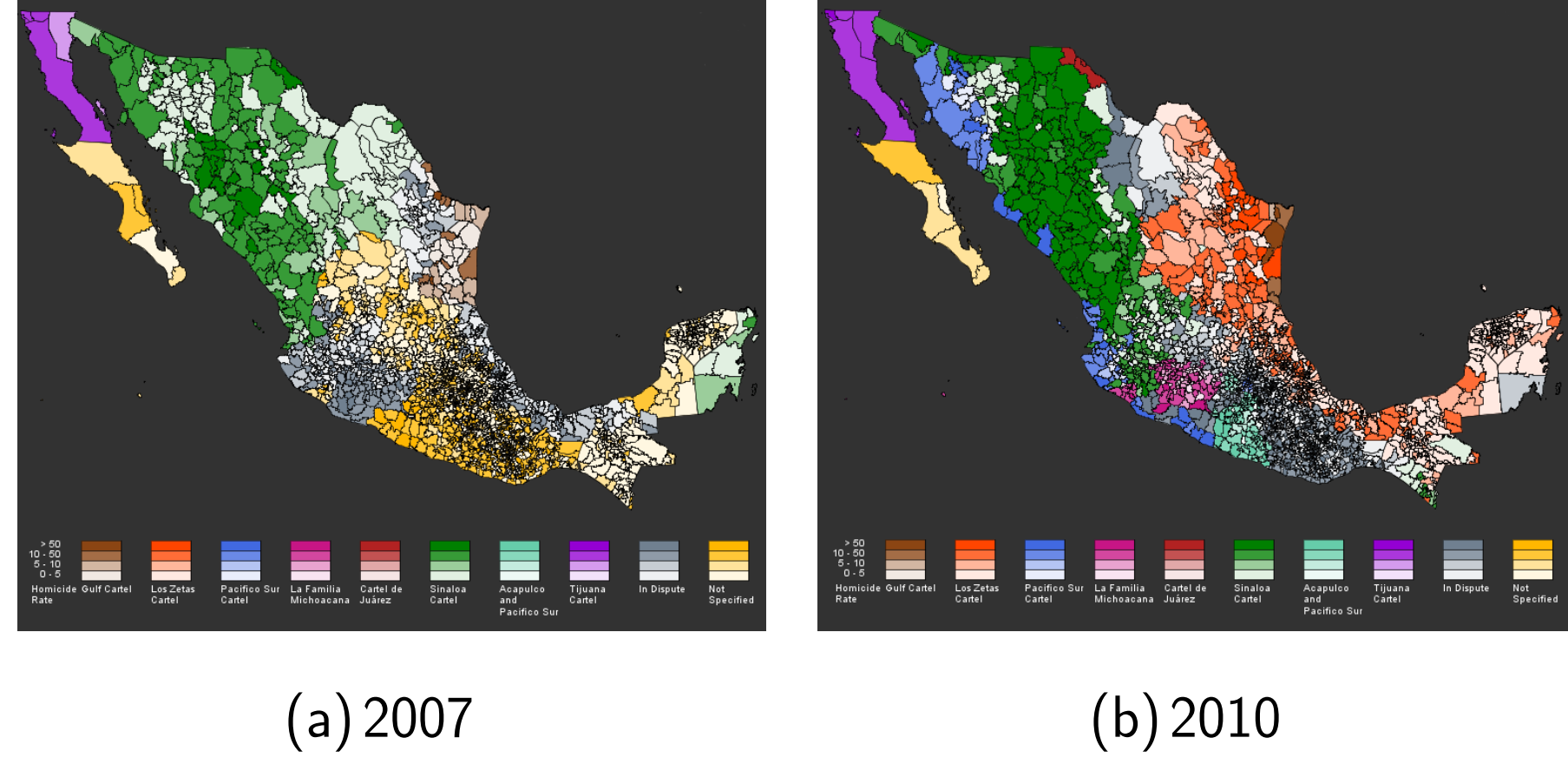
# Visualization and Causal Inference of the Mexican Drug War

Valeria Espinosa and Joseph Kelly

vespinos@fas.harvard.edu, kelly2@fas.harvard.edu

Statistics Department, Harvard University

## Visualize the problem



We attempt to answer whether **homicide rates increase significantly after a military intervention**.

## Estimand

Let  $Y_i(1)$  denote the homicide rate change in region  $i$  from 2006 to one year after receiving a military intervention, and  $Y_i(0)$  what it would have been if it hadn't received it (Rubin Causal Model). Our estimand is the average causal effect of the military intervention,  $W$ , for the regions that were intervened ( $W = 1$ ),

$$\tau = Y(1) - Y(0) = \frac{\sum_{i=1}^I Y_i(1) - Y_i(0)}{I}.$$

Let  $N_i$  denote the number of municipalities that correspond to region  $i$ , then

$$Y_i(1) = \frac{\sum_{j=1}^{N_i} w_{ij} Y_{ij}(1)}{N_i} \text{ and } Y_i(0) = \frac{\sum_{j=1}^{N_i} w_{ij} Y_{ij}(0)}{N_i},$$

$$\text{where } w_{ij} = \frac{\text{Pop}_{ij}}{\text{Pop}_i} \text{ and } \text{Pop}_i = \sum_j \text{Pop}_{ij}.$$

However,  $Y_i(0)$  and  $Y_{ij}(0)$  are missing  $\forall i, j$ .

## Key Assumptions

- SUTVA**
  - No hidden values of treatments** Broad definition of treatment: at least one municipality in the region received an intervention between 2007-2010, or not ([2]).
  - No interference between units** Grouped close regions that received an intervention, and their neighboring municipalities to make the “no interference” assumption more reasonable.
- Unconfoundedness** We assume we have all covariates,  $\mathbf{X}$ , such that given  $\mathbf{X}$ , treatment assignment is independent of  $\mathbf{Y}$ .
- Missing Data** One covariate had missing values. We exactly matched on missingness pattern and Political Party in municipality before Calderón.

## Estimation & Visualization

2213 municipalities were included in the initial control pool, and 13 regions (205 municipalities) were considered the treated units. Propensity score matching was used to identify a set of 5 control municipalities that look like each treated ones, and ultimately estimate  $Y_{ij}(0)$  and  $Y_i(0)$ . Let  $M_{ij}$  be the number of municipalities matched to the  $j$ th municipality in region  $i$ , and  $\text{PopM}_{ij} = \sum_{k=1}^{M_{ij}} \text{PopM}_{ijk}$  is the sum of their populations. Then,

$$\hat{Y}_{ij}(0) = \frac{M_{ij}}{\sum_{k=1}^{M_{ij}} v_{ijk}} Y_{ijk}(0), \text{ where } v_{ijk} = \frac{\text{PopM}_{ijk}}{\text{PopM}_{ij}}.$$

Therefore,

$$\hat{Y}_i(0) = \frac{N_i}{\sum_{j=1}^{N_i} w_{ij}} \hat{Y}_{ij}(0) = \frac{N_i}{\sum_{j=1}^{N_i} w_{ij}} \frac{M_{ij}}{\sum_{k=1}^{M_{ij}} v_{ijk}} Y_{ijk}(0) = \frac{N_i}{\sum_{j=1}^{N_i} \sum_{k=1}^{M_{ij}} \tilde{w}_{ijk}} \tilde{w}_{ijk} Y_{ijk}(0) \text{ with } \tilde{w}_{ijk} = w_{ij} v_{ijk},$$

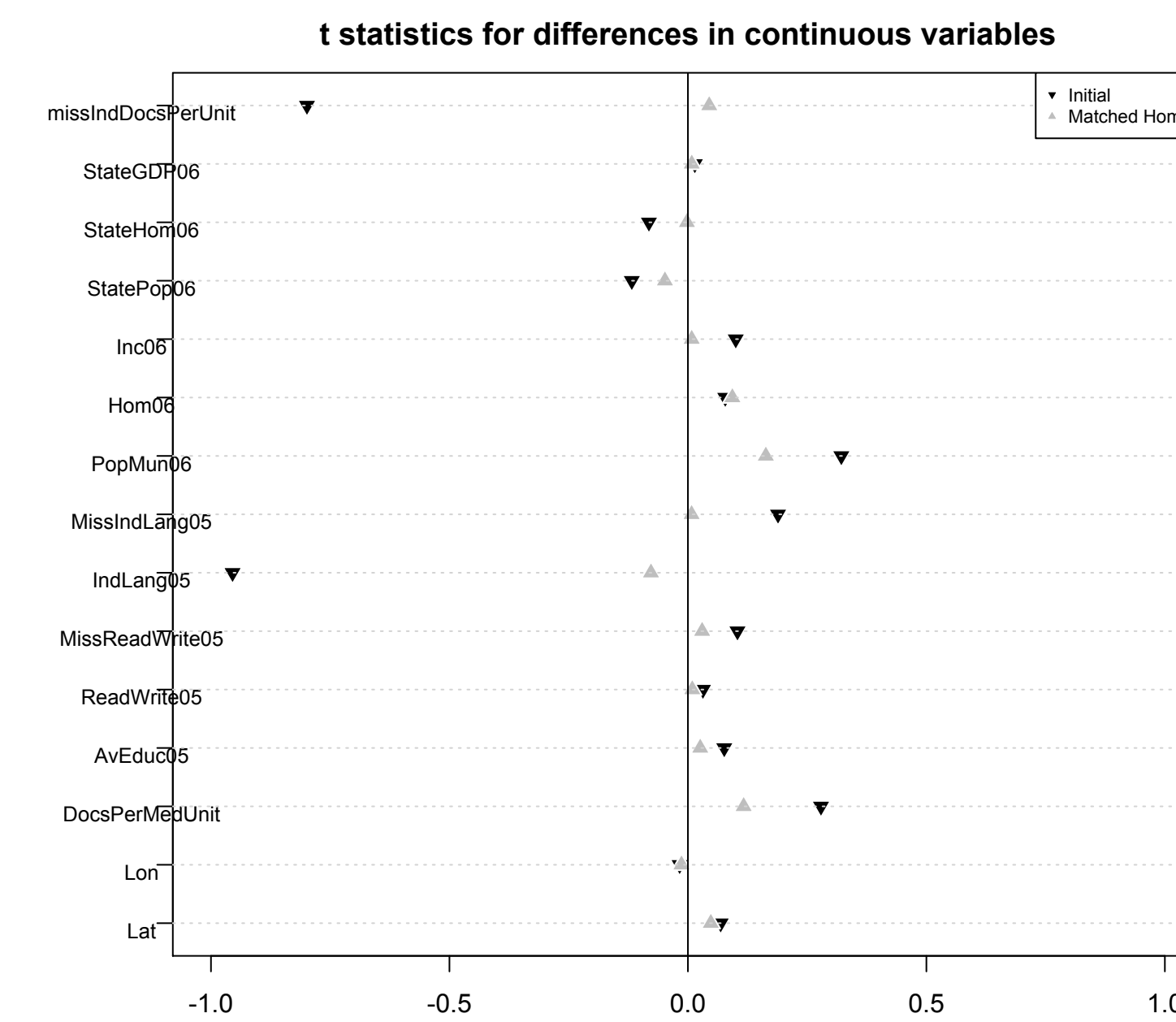
and

$$\hat{\tau} = \frac{\sum_j Y_j(1)}{J} - \frac{\sum_{j=1}^J \hat{Y}_j(0)}{J} = Y(1) + Y(0).$$

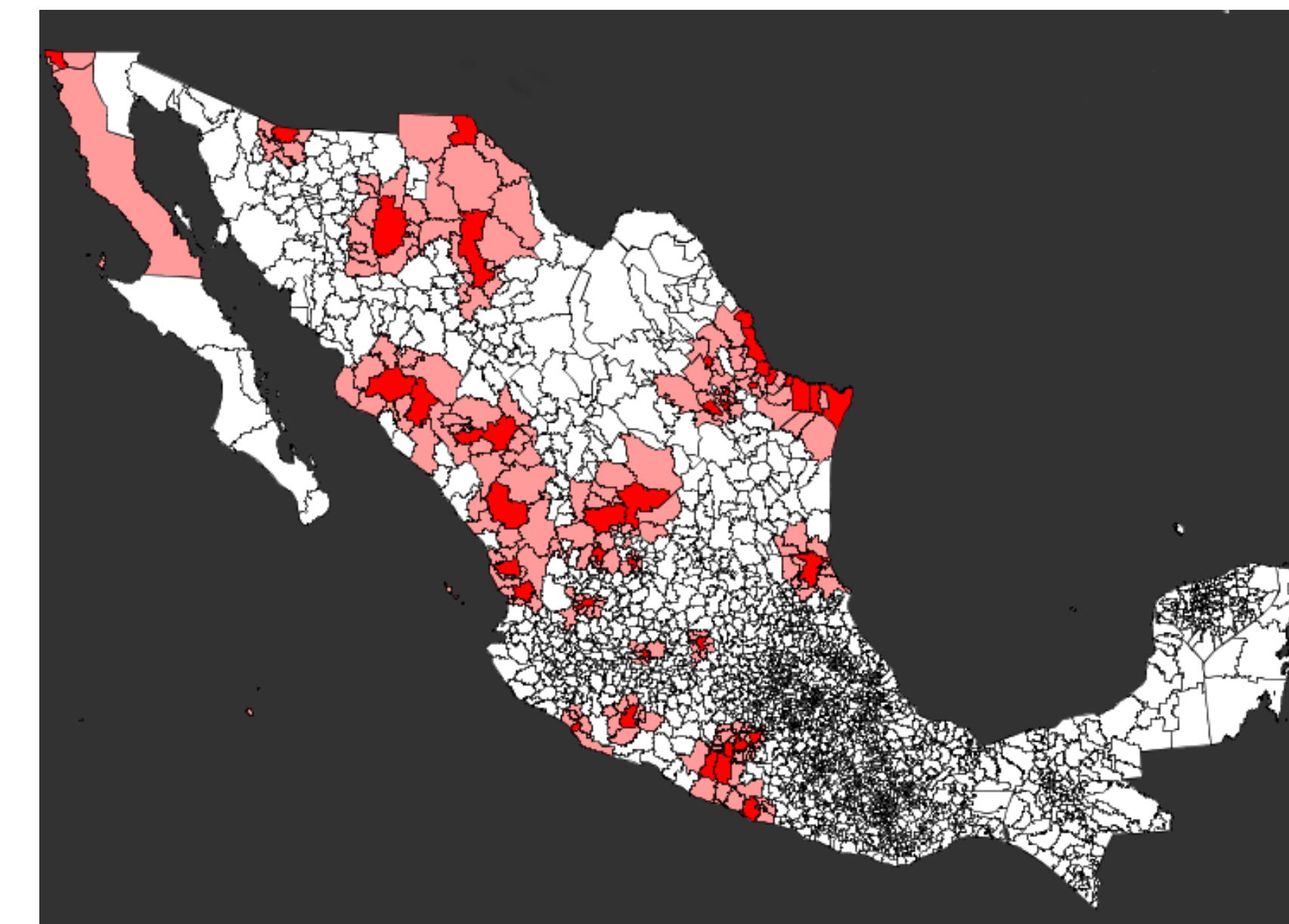
We know that  $\text{var}(\hat{\tau})$  is largest under additivity of potential outcomes. In that case  $\text{var}(\hat{\tau}) = \text{var}(Y(1)) + \text{var}(Y(0))$ . We use that over estimate to get confidence intervals. Now,

$$\begin{aligned} \text{var}(\hat{Y}(0)) &= E(\text{var}(\hat{Y}(0)|Y_i(0)\forall i)) + \text{var}(E(\hat{Y}(0)|Y_i(0)\forall i)) = E(\sum \text{var}(\hat{Y}_i(0))/I) + \text{var}(\sum Y_i(0)/I) \\ &= E(\frac{\sum_{j,k} w_{ijk} (Y_{ijk}(0) - Y_i(0))^2}{1 - \sum_{j,k} w_{ijk}^2}) + \text{var}(Y(0))/I = \frac{\sum_{i,j,k} w_{ijk} (Y_{ijk}(0) - Y_i(0))^2}{I(1 - \sum_{j,k} w_{ijk}^2)} + S^2(0)/I. \end{aligned}$$

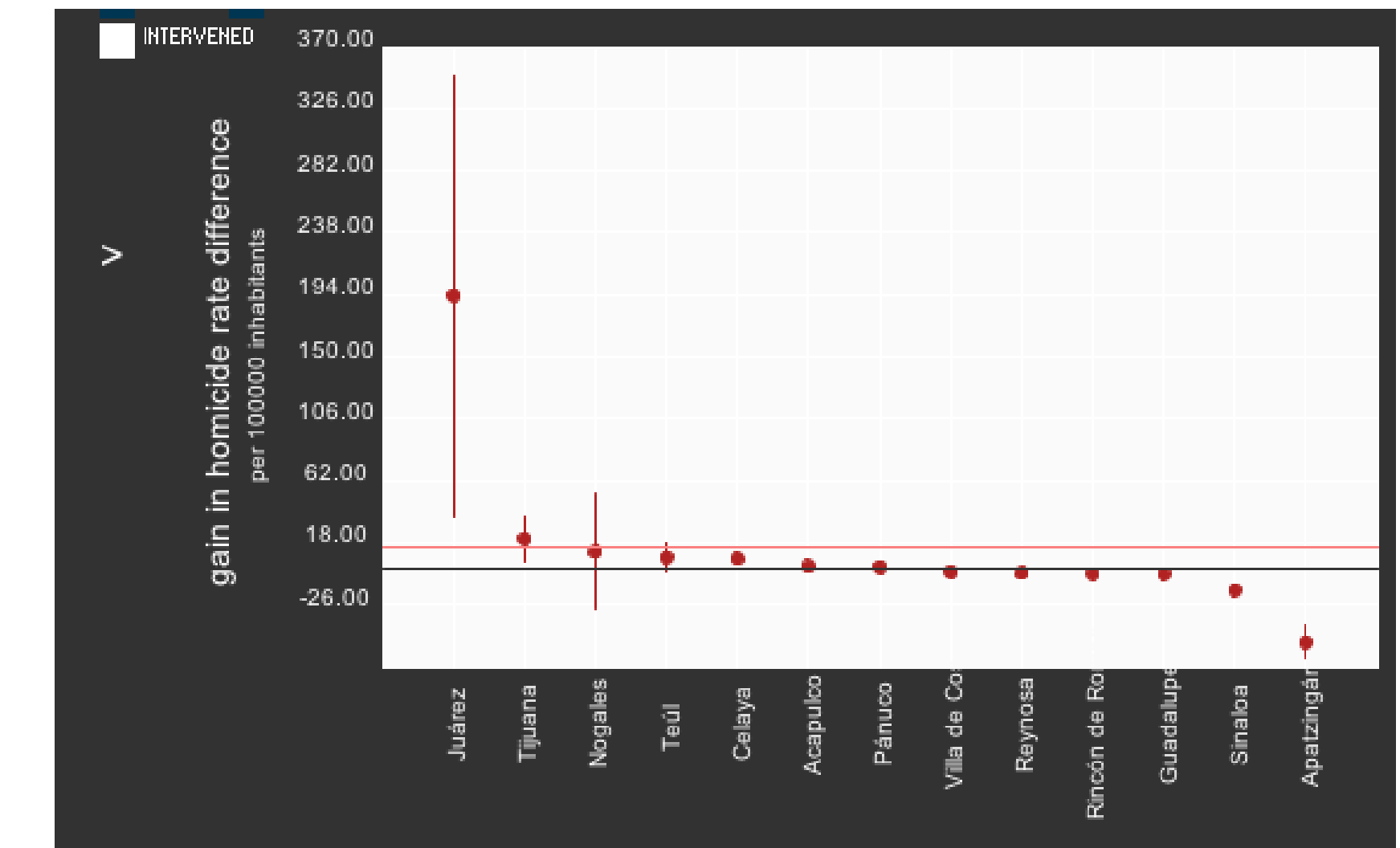
Now,  $\text{var}(\hat{Y}(1)) = S^2(1)/I$  because the all  $Y_j(1)$  are observed.



(c) Love plot - balance checks



(d) Interventions and SUTVA



(e) Results

## Results

unit	Region	number of municipalities intervention	Date of first $Y_j(1) - Y_j(0)$ (SD)
4	Juárez	15	2009 192.99 (79.88)
1	Tijuana	5	2008 20.49 (8.27)
2	Nogales	5	2008 11.41 (20.90)
10	Teúl de González Ortega	10	2009 7.32 (4.99)
15	Celaya	9	2009 6.74 (1.37)
18	Acapulco	35	2008 1.19 (0.77)
5	Pánuco	14	2007 0.37 (0.24)
9	Villa de Cos, Fresnillo	18	2008 -2.87 (0.34)
6	Reynosa	24	2008 -3.49 (1.48)
11	Rincón de Romos	8	2008 -4.10 (1.05)
8	Guadalupe	20	2009 -4.27 (0.58)
12	Sinaloa, Badiraguato, Pueblo Nuevo	27	2007 -15.84 (0.74)
16	Apatzingán	10	2007 -52.81 (5.97)
$\bar{\tau}$		205	- 14.61 (23.14)

## Key References & Data Source

- [1] Abadie Synthetic Matching
- [2] Escalante F, *Homicidios 2008-2009 La muerte tiene permiso*
- [3] Imbens G. & Rubin D.R., (2012)
- [4] Rubin D.R. ,*Matched Sampling for Causal Effects*,
- [5] CIDAC
- [6] INEGI
- [7] Stratfor Maps