Online Supplementary Materials

Appendix A: Earthquake intensity levels

Using the estimated PGA, we created three measures of exposure to the earthquake: one with three levels, another with five levels, and a final one with ten levels.

We defined the exposure with three intensity levels as follows.

- Low PGA (PGA<0.08): felt by many people indoors; no buildings received damage.
- Medium PGA ($0.08 \leq$ PGA ≤ 0.25): felt by most or all people indoors; some people were frightened; damages in some (non-resistant) buildings.
- High PGA (PGA>0.25): many people were frightened; severe shaking; damages in resistant buildings.

For the versions of the exposure with five and ten levels, we divided the students into PGA quintiles and deciles, respectively.

Appendix B: Covariate profiles

Table 6: Covariate profile of the population and template sample

Covariate	Population	Template
Female	0.54	0.51
Indigenous		
Indigenous	0.08	0.07
Missing	0.15	0.14
Father's education		
Secondary	0.39	0.40
Technical	0.09	0.09
College	0.15	0.14
Missing	0.05	0.04
Mother's education		
Secondary	0.41	0.43
Technical	0.13	0.12
College	0.12	0.12
Missing	0.01	0.01
Household income (2008 CL$1000)		
100-200	0.26	0.26
200-400	0.30	0.31
400-600	0.13	0.12
600-1400	0.13	0.14
1400 or more	0.09	0.09
Missing	0.01	0.02
Number of books at home		
1-10	0.19	0.19
11-50	0.46	0.46
51-10	0.16	0.16
More than 100	0.16	0.16
Missing	0.01	0.01

Table 6 (continued): Covariate profile of the population and template sample

Covariate	Population	Template
Student's attendance (deciles)		
2	0.12	0.11
3	0.08	0.09
4	0.10	0.10
5	0.13	0.13
6	0.08	0.08
7	0.09	0.09
8	0.10	0.09
9	0.11	0.10
10	0.15	0.16
Student's GPA 2008 (deciles)		
2	0.11	0.11
3	0.11	0.09
4	0.10	0.11
5	0.10	0.10
6	0.10	0.11
7	0.09	0.09
8	0.10	0.10
9	0.09	0.10
10	0.08	0.08
Student's test scores (deciles)		
2	0.08	0.07
3	0.09	0.10
4	0.09	0.10
5	0.10	0.10
6	0.10	0.11
7	0.11	0.10
8	0.12	0.12
9	0.12	0.11
10	0.12	0.13
Missing	0.01	0.01
School administration		
Public	0.34	0.34
Private subsidized (voucher)	0.55	0.55
Rural school	0.03	0.02
Catholic school	0.24	0.23
School SES		
Mid-low	0.32	0.32
Medium	0.29	0.30
Mid-high	0.18	0.17
High	0.11	0.12
School's test scores (deciles)		
2	0.07	0.07
3	0.09	0.07
4	0.09	0.09
5	0.10	0.11
6	0.11	0.12
7	0.10	0.11
8	0.12	0.12
9	0.12	0.11
10	0.13	0.13

Appendix C: Proofs

To prove Proposition 4.2 we use the following lemma.

Lemma 6.1. *Let* $(\boldsymbol{z}, \boldsymbol{v})$ *be a feasible solution for the LP relaxation of* (4) *that satisfies all inequalities* (4b) *at equality. Furthermore, let* $\underline{\boldsymbol{z}}$ *and* $\overline{\boldsymbol{z}}$ *be such that*

- $\boldsymbol{z} = \frac{1}{2}\underline{\boldsymbol{z}} + \frac{1}{2}\overline{\boldsymbol{z}}$ *and,*
- $\max\left\{\left|\sum_{\ell\in\mathcal{L}_{p,k}} \underline{z}_\ell - \sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right|, \left|\sum_{\ell\in\mathcal{L}_{p,k}} \overline{z}_\ell - \sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right|\right\} \leq v_{p,k}$ *for all* $p \in \mathcal{P}$ *and* $k \in \mathcal{K}(p)$.

If $\underline{\boldsymbol{v}}$ *and* $\overline{\boldsymbol{v}}$ *are such that for all* $p \in \mathcal{P}$ *and* $k \in \mathcal{K}(p)$,

- $\underline{v}_{p,k} = v_{p,k} + \operatorname{sign}\left(\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell - N_{p,k}\right)\left(\sum_{\ell\in\mathcal{L}_{p,k}} \underline{z}_\ell - \sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right)$, *and*
- $\overline{v}_{p,k} = v_{p,k} + \operatorname{sign}\left(\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell - N_{p,k}\right)\left(\sum_{\ell\in\mathcal{L}_{p,k}} \overline{z}_\ell - \sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right)$,

where $\operatorname{sign}(w) = w/|w|$, *then we have that*

$$(\underline{\boldsymbol{z}}, \underline{\boldsymbol{v}}) \text{ and } (\overline{\boldsymbol{z}}, \overline{\boldsymbol{v}}) \text{ are feasible for the LP relaxation of (4), and} \tag{5a}$$

$$(\boldsymbol{z},\ \boldsymbol{v}) = \frac{1}{2}(\underline{\boldsymbol{z}}, \underline{\boldsymbol{v}}) + \frac{1}{2}(\overline{\boldsymbol{z}}, \overline{\boldsymbol{v}}). \tag{5b}$$

Proof. Condition (5a) follows by noting that under the equality assumption on (4b), for all $p \in \mathcal{P}$ and $k \in \mathcal{K}(p)$ we have that if $\varepsilon < v_{p,k}$, then

$$\left|\left(\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right) + \varepsilon - N_{p,k}\right| = v_{p,k} + \operatorname{sign}\left(\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell - N_{p,k}\right)\varepsilon \tag{6}$$

$$\left|\left(\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right) - \varepsilon - N_{p,k}\right| = v_{p,k} - \operatorname{sign}\left(\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell - N_{p,k}\right)\varepsilon. \tag{7}$$

Condition (5b) follows by noting that $\boldsymbol{z} = \frac{1}{2}\underline{\boldsymbol{z}} + \frac{1}{2}\overline{\boldsymbol{z}}$ implies $\left(\sum_{\ell\in\mathcal{L}_{p,k}} \underline{z}_\ell - \sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right) = -\left(\sum_{\ell\in\mathcal{L}_{p,k}} \overline{z}_\ell - \sum_{\ell\in\mathcal{L}_{p,k}} z_\ell\right)$ for all $p \in \mathcal{P}$ and $k \in \mathcal{K}(p)$.

□

Proof of Proposition 4.2. In both cases we show that for any non-integral point $(\boldsymbol{z},\ \boldsymbol{v})$ that is feasible for the LP relaxation of (4), there exist $(\underline{\boldsymbol{z}}, \underline{\boldsymbol{v}})$ and $(\overline{\boldsymbol{z}}, \overline{\boldsymbol{v}})$ that satisfy (5) and $(\underline{\boldsymbol{z}}, \underline{\boldsymbol{v}}) \neq (\overline{\boldsymbol{z}}, \overline{\boldsymbol{v}})$, which implies that non-integral points cannot be extreme points.

First note that if there exist $p \in \mathcal{P}$ and $k \in \mathcal{K}(p)$ for which $\varepsilon := v_{p,k} - \left|\sum_{\ell\in\mathcal{L}_{p,k}} z_\ell - N_{p,k}\right| > 0$, then by letting $(\underline{\boldsymbol{z}}, \underline{\boldsymbol{v}}) = (\overline{\boldsymbol{z}}, \overline{\boldsymbol{v}}) = (\boldsymbol{z},\ \boldsymbol{v})$ and changing $\underline{v}_{p,k}$ to $v_{p,k} - \varepsilon$ and $\overline{v}_{p,k}$ to $v_{p,k} + \varepsilon$ we satisfy (5) and $(\underline{\boldsymbol{z}}, \underline{\boldsymbol{v}}) \neq (\overline{\boldsymbol{z}}, \overline{\boldsymbol{v}})$. Hence, without loss of generality we may assume that $(\boldsymbol{z},\ \boldsymbol{v})$ satisfies all constraints (4b) at equality.

Under the equality assumption on (4b), for all $p \in \mathcal{P}$ and $k \in \mathcal{K}(p)$ we have that

$$v_{p,k} \notin \mathbb{Z}_+ \text{ or } |\{\ell \in \mathcal{L}_{p,k} \,:\, z_\ell \in (0,1)\}| \neq 1. \tag{8}$$

For case 1 it suffices to prove the result for $P = 2$ (The result follows for $P = 1$ by copying the covariate as the result for $P = 2$ does not require that the covariates are different). For $P = 2$, we may use (8) (and the assumption that at least one z_l is fractional) to construct sequences $\{s_1, \ldots, s_S\} \subseteq \{1, \ldots, L\}$ and $\{r_1, \ldots, r_{S+1}\} \subseteq \{1, \ldots, \max\{K_{p_1}, K_{p_2}\}\})$ such that (without loss of generality by possibly interchanging p_1 and p_2):

- $s_i \neq s_j$ for all $i, j \in \{1, \ldots, S\}$ with $i \neq j$,
- $r_i \neq r_j$ for all $i, j \in \{1, \ldots, S+1\}$ with $i < j$, $(i-j)/2 \in \mathbb{Z}$ and $(i, j) \neq (1, S+1)$,
- $z_{\ell_{s_j}} \in (0,1)$ for all $j \in \{1, \ldots, S\}$,
- $k_{r_j} \in \mathcal{K}\left(p_{h(j)}\right)$ for all $j \in \{1, \ldots, S+1\}$ where

$$h(j) = 2 - j + 2\lfloor j/2 \rfloor = \begin{cases} 1 & j \text{ is odd} \\ 2 & j \text{ is even,} \end{cases}$$

- $\ell_{s_j} \in \mathcal{L}_{p_{h(j)}, k_{r_j}}$ and $\ell_{s_j} \in \mathcal{L}_{p_{h(j+1)}, k_{r_{j+1}}}$ for all $j \in \{1, \ldots, S\}$,

and either

$$S \text{ is even, } h(1) = h(S+1) \text{ and } r_1 = r_{S+1} \tag{9}$$

or

$$v_{p_{h(1)}, k_{r_1}}, v_{p_{h(S+1)}, k_{r_{S+1}}} \notin \mathbb{Z}, \tag{10a}$$

$$\left\{\ell \in \mathcal{L}_{p_{h(1)}, k_{r_1}} \,:\, z_\ell \in (0,1)\right\} = \{\ell_{s_1}\}, \tag{10b}$$

$$\left\{\ell \in \mathcal{L}_{p_{h(S+1)}, k_{r_{S+1}}} \,:\, z_\ell \in (0,1)\right\} = \{\ell_{s_S}\}. \tag{10c}$$

If (9) holds, let $\varepsilon = \min_{i=1}^{S}\left\{z_{\ell_{s_j}}, 1 - z_{\ell_{s_j}}\right\} > 0$, $\underline{\boldsymbol{z}}$ and $\overline{\boldsymbol{z}}$ be such that

$$\underline{z}_{\ell_i} = \begin{cases} z_{\ell_i} - \varepsilon & \text{if } i = s_j \text{ for an odd } j \in S, \\ z_{\ell_i} + \varepsilon & \text{if } i = s_j \text{ for an even } j \in S, \\ z_{\ell_i} & \text{otherwise} \end{cases} \tag{11a}$$

$$\overline{z}_{\ell_i} = \begin{cases} z_{\ell_i} + \varepsilon & \text{if } i = s_j \text{ for an odd } j \in S, \\ z_{\ell_i} - \varepsilon & \text{if } i = s_j \text{ for an even } j \in S, \\ z_{\ell_i} & \text{otherwise.} \end{cases} \tag{11b}$$

The result follows from Lemma 6.1 (with $\underline{\boldsymbol{v}} = \overline{\boldsymbol{v}} = \boldsymbol{v}$) because $\sum_{\ell \in \mathcal{L}_{p,k}} \underline{z}_\ell = \sum_{\ell \in \mathcal{L}_{p,k}} \overline{z}_\ell = \sum_{\ell \in \mathcal{L}_{p,k}} z_\ell$ for all $p \in \mathcal{P}$ and $k \in \mathcal{K}(p)$.

If instead (10) holds let

$$\varepsilon = \min \left\{ \min_{i=1}^{S} \left\{ z_{\ell_{s_j}}, 1 - z_{\ell_{s_j}} \right\}, v_{p_{h(1)},k_{r_1}}, v_{p_{h(S+1)},k_{r_{S+1}}} \right\}$$

$\underline{\boldsymbol{z}}$ and $\overline{\boldsymbol{z}}$ be as defined in (11) with this new ε, and the result again follows from Lemma 6.1 by noting that (10a) implies ε remains strictly positive.

For case 2 we only need to prove the result for $P \geq 3$. By (8) (and the assumption that at least one z_l is fractional), there exist $k \in \mathcal{K}(p_P)$ such that either $|\{\ell \in \mathcal{L}_{p_P,k} \, : \, z_\ell \in (0,1)\}| \geq 2$ or, $|\{\ell \in \mathcal{L}_{p_P,k} \, : \, z_\ell \in (0,1)\}| = 1$ and $v_{p_P,k} > 0$.

In the first case let $s_1 \neq s_2$ be such that $\ell_{s_1}, \ell_{s_2} \in \{\ell \in \mathcal{L}_{p_P,k} \, : \, z_\ell \in (0,1)\}$, $\varepsilon = \min_{i=1}^{2} \left\{ z_{\ell_{s_j}}, 1 - z_{\ell_{s_j}} \right\} > 0$, and $\underline{\boldsymbol{z}}$ and $\overline{\boldsymbol{z}}$ be such that

$$\underline{z}_{\ell_i} = \begin{cases} z_{\ell_i} - \varepsilon & \text{if } i = s_1, \\ z_{\ell_i} + \varepsilon & \text{if } i = s_2, \\ z_{\ell_i} & \text{otherwise} \end{cases}$$

$$\overline{z}_{\ell_i} = \begin{cases} z_{\ell_i} + \varepsilon & \text{if } i = s_1, \\ z_{\ell_i} - \varepsilon & \text{if } i = s_2, \\ z_{\ell_i} & \text{otherwise.} \end{cases}$$

Then $\sum_{\ell \in \mathcal{L}_{p_P,k}} \underline{z}_\ell = \sum_{\ell \in \mathcal{L}_{p_P,k}} \overline{z}_\ell = \sum_{\ell \in \mathcal{L}_{p_P,k}} z_\ell$ for all $k \in \mathcal{K}(p_P)$. Furthermore, by assumption, for all $k \in \mathcal{K}(p_P)$ and $i \in \{1, \ldots, P-1\}$ there exist $k' \in \mathcal{K}(p_i)$ such that $\mathcal{L}_{p_P,k} \subseteq \mathcal{L}_{p_i,k'}$, so we also have $\sum_{\ell \in \mathcal{L}_{p,k}} \underline{z}_\ell = \sum_{\ell \in \mathcal{L}_{p,k}} \overline{z}_\ell = \sum_{\ell \in \mathcal{L}_{p,k}} z_\ell$ for all $p \in \mathcal{P}$ and $k \in \mathcal{K}(p)$. The result then follows from Lemma 6.1 (with $\underline{\boldsymbol{v}} = \overline{\boldsymbol{v}} = \boldsymbol{v}$).

In the second case, let $s \in \{1, \ldots, L\}$ be such that $\{\ell_s\} = \{\ell \in \mathcal{L}_{p_P,k} \, : \, z_\ell \in (0,1)\}$,

$$\varepsilon = \min \left\{ z_{\ell_s}, 1 - z_{\ell_s}, \min \left\{ \min \left\{ v_{p,k'}, 1 - v_{p,k'} \right\} \, : \, p \in \mathcal{P}, \quad k' \in \mathcal{K}(p) \text{ such that } \ell_s \in \mathcal{L}_{p,k'} \right\} \right\},$$

and $\underline{\boldsymbol{z}}$ and $\overline{\boldsymbol{z}}$ be such that

$$\underline{z}_{\ell_i} = \begin{cases} z_{\ell_i} - \varepsilon & \text{if } i = s, \\ z_{\ell_i} & \text{otherwise} \end{cases}$$
$$\overline{z}_{\ell_i} = \begin{cases} z_{\ell_i} + \varepsilon & \text{if } i = s, \\ z_{\ell_i} & \text{otherwise.} \end{cases}$$

By assumption, for all $i \in \{1, \ldots, P-1\}$ there exist $k' \in \mathcal{K}(p_i)$ such that $\mathcal{L}_{p_P,k} \subseteq \mathcal{L}_{p_i,k'}$ and $\mathcal{T}_{p_P,k} \subseteq \mathcal{T}_{p_i,k'}$ so, $v_{p_P,k} > 0$ implies that $v_{p,k'} > 0$ for all $p \in \mathcal{P}$ and $k' \in \mathcal{K}(p)$ such that $\ell_s \in \mathcal{L}_{p,k'}$. Then $\varepsilon > 0$ and the result follows from Lemma 6.1. □

Proof of Lemma 4.3. Let

$$\begin{aligned} \mathbf{x}_1 &= (k_1, k_1, k_1), \quad \mathbf{x}_2 = (k_3, k_3, k_3), \\ \mathbf{x}_1 &= (k_1, k_2, k_3), \quad \mathbf{x}_2 = (k_3, k_2, k_1), \\ \mathbf{x}_1 &= (k_2, k_1, k_2), \quad \mathbf{x}_2 = (k_2, k_3, k_2), \end{aligned}$$

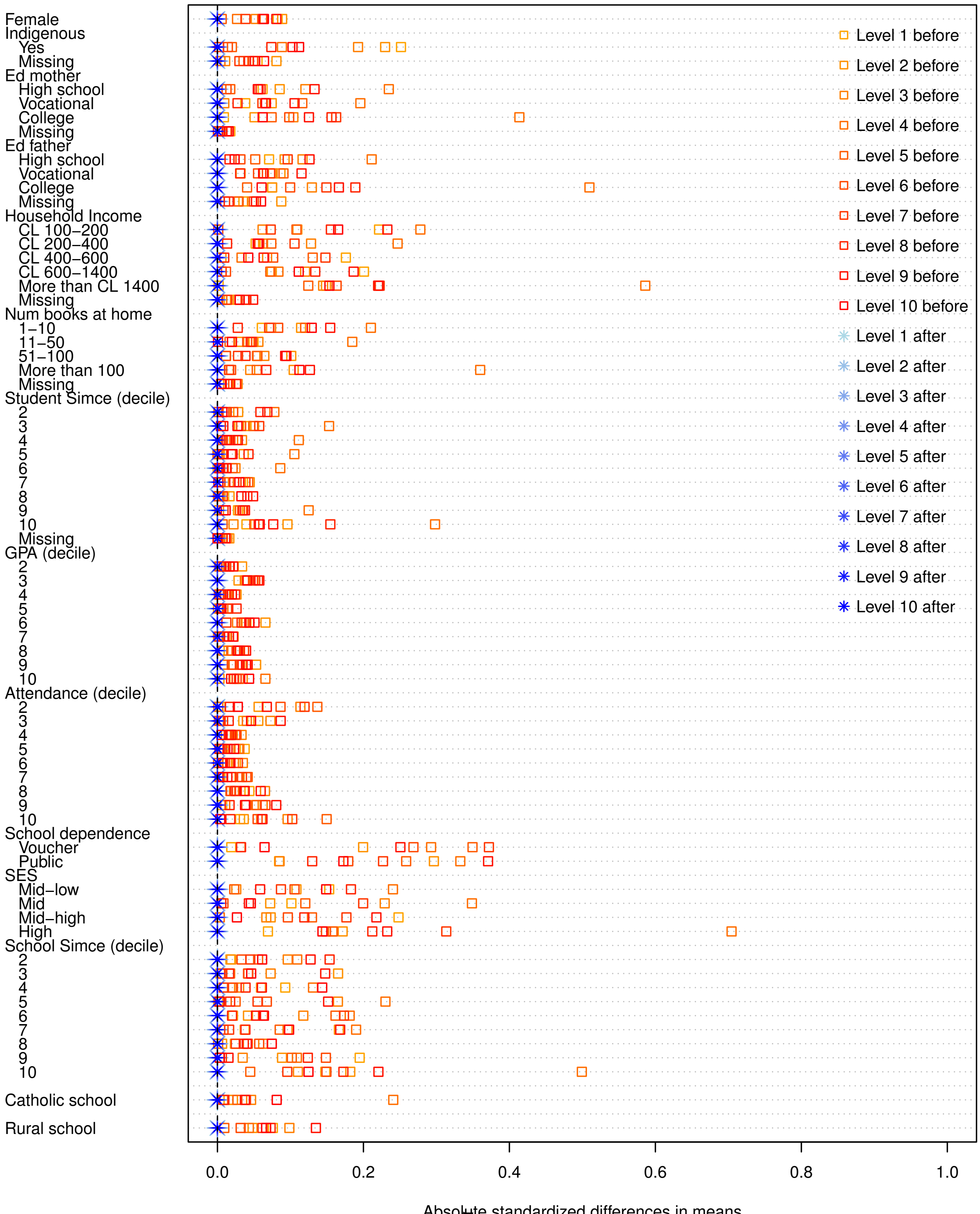
$T = 3$, $L = 6$ and $N_{p,k} = 1$ for all p and k. The feasible region of the LP relaxation of (4) for this case is given by

$$\begin{array}{lll} |z_{\ell_1} + z_{\ell_3} - 1| \le v_{p_1,k_1}, & |z_{\ell_5} + z_{\ell_6} - 1| \le v_{p_1,k_2}, & |z_{\ell_2} + z_{\ell_4} - 1| \le v_{p_1,k_3}, \\ |z_{\ell_1} + z_{\ell_5} - 1| \le v_{p_2,k_1}, & |z_{\ell_3} + z_{\ell_4} - 1| \le v_{p_2,k_2}, & |z_{\ell_2} + z_{\ell_6} - 1| \le v_{p_2,k_3} \\ |z_{\ell_1} + z_{\ell_4} - 1| \le v_{p_3,k_1}, & |z_{\ell_5} + z_{\ell_6} - 1| \le v_{p_3,k_2}, & |z_{\ell_2} + z_{\ell_3} - 1| \le v_{p_3,k_3} \\ \sum_{i=1}^{6} z_{\ell_i} = 1, & 0 \le z_{\ell_i} \le 1 & \forall i \in \{1, \ldots, 6\}. \end{array}$$

Using CDDLib (Fukuda 2001) we can check that this LP has 11 fractional extreme points out of a total of 31. In particular, $z_{\ell_i} = 1/2$ for all $i \in \{1, \ldots, 6\}$ and $v_{p,k} = 0$ for all p and k is one such fractional extreme point. Finally, Proposition 4.1 implies that (1) for this data also fails to be integral. □

Appendix D: Covariate balance

Figure 3: Standardized differences in means in covariates before and after matching for 10 levels of exposure.



Appendix E: Effect estimates

Table 7: Effect estimates and 95% confidence intervals for different levels of exposure to the earthquake. The point estimates are contrasts with respect to exposure level 1. The 95% confidence account for multiple comparisons.

(a) 3 exposure levels

Exposure level	Attendance (%)	PSU score
2	-1.00	11.00
	[-2.01,0.00]	[1.90,18.50]
3	-11.85	8.00
	[-12.35,-11.00]	[1.50,14.10]

(b) 5 exposure levels

Exposure level	Attendance (%)	PSU score
2	-0.00	6.00
	[-1.00,1.00]	[-0.60,14.00]
3	-2.55	6.50
	[-4.00,-1.99]	[-0.10,13.50]
4	-4.00	4.50
	[-5.01,-3.00]	[-3.00,11.00]
5	-12.95	8.50
	[-13.70,-12.09]	[0.90,15.10]

(c) 10 exposure levels

Exposure level	Attendance (%)	PSU score
2	0.00	4.00
	[-0.01,1.01]	[-3.50,11.60]
3	0.00	9.00
	[-1.00,1.01]	[0.90,17.10]
4	-1.00	10.00
	[-2.00,0.01]	[2.00,17.60]
5	-2.00	9.00
	[-2.16,-0.99]	[0.90,16.50]
6	-3.00	7.50
	[-4.01,-2.00]	[-0.50,14.50]
7	-2.00	-3.50
	[-3.01,-1.69]	[-3.60,11.00]
8	-6.10	-4.00
	[-7.66,-5.00]	[-4.10,11.10]
9	-11.80	9.00
	[-12.85,-10.80]	[1.50,17.50]
10	-13.75	10.50
	[-14.56,-12.94]	[3.0,18.60]