Online Supplementary Material for: "Heterogeneous Peer Effects and Rank Concerns: Theory and Evidence"

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1 Intensity Attenuation Formula

To generate the intensity attenuation formula for the 2010 Maule earthquake, engineers visited 111 towns after the earthquake struck and evaluated the damage to at least 20 buildings per town by direct observation. Each building was assigned a damage grade (DG). There are six damage grades, ranging from *no damage* to *collapse*, and they are described in Table 1. The information on damage to individual buildings in each sampled town is aggregated into a town-wide measure of seismic intensity (on the MSK scale). Importantly, intensity on the MSK scale is independent of the distribution of house types in a town.

To understand how the assignment of MSK intensity works formally, consider a simplified example with only two building types and only two levels of damage. Assume that in town i there are only two types of houses, a fraction α are adobe houses and a fraction $1-\alpha$ are reinforced masonries. Assume also that each house can suffer only two types of damage grade (DG): high (H) or low (L), with $H, L \in R$ and $H > L$. Let $I_i \in [0,1]$ denote MSK intensity in town i. If a fraction x of all adobe houses suffer damage H, then we assign MSK intensity $I_i = x$ to town i. x is the damage ratio for adobe houses. Reinforced masonry houses are more resistant than adobe houses. Therefore, engineers know that when $I_i = x$ only a fraction $x - \Delta_m$ of all reinforced masonries suffer damage H, where $\Delta_m > 0$ captures the additional resistance of reinforced masonries over adobe houses. Hence, an alternative way to assign an MSK intensity to town i is to look at the damage to reinforced masonries: if a fraction y of reinforced masonries suffers damage H, then $I_i = y + \Delta_m$. Notice that the assignment of the MSK intensity does not depend on the distribution of house types, i.e. I_i is independent of α.[1] MSK intensity, though based on observed damages which vary by building type, is constructed in such a way that it signals intensity of the seismic event in a town, and not overall damage to that town.

The mapping from damage grade in individual buildings to a town-wide measure of MSK intensity can be found in Table 2 in Astroza et al. (2012), reporting damage grade and damage ratios. Table 2 reports the damage grade and ratios for the two building types in my sample: old traditional adobe constructions (11%) and unreinforced masonry houses (89%). These two building

[1] There is a redundancy due to the fact that Δ_m is known. It is sufficient to look at damage in one type of house, because the damage to other types of houses can be inferred. In practice, engineers look simultaneously at damage to all types of houses.

Table 1: Description of damage grades to individual structures

Grade	Description
G0	No damage
G1	Slight damage: fine cracks in plaster; falling of small pieces of plaster
G2	Moderate damage: fine cracks in walls; vertical cracks at wall intersections; horizontal cracks in chimneys, parapets and gables; spalling of fairly large pieces of plaster; falling of parts of chimneys; sliding of rood tiles
G3	Heavy damage (uninhabitable): large and deep diagonal cracks in most walls; large and deep vertical cracks at wall intersections; some walls lean out-of-plumb; falling of chimneys, parapets and gable walls; falling of rood tiles
G4	Very heavy damage (uninhabitable): partial or total collapse of a wall in the building; collapse of building partitions
G5	Collapse or destruction (uninhabitable): collapse of two or more walls in the building

types have similar earthquake resistance.

2 Estimation of reconstruction costs

To estimate reconstruction costs, I use the damage ratios proposed in Bommer et al. (2002) and reported in Table 2.[2] In their study, the authors develop a technique to estimate earthquake restoration costs for Turkish catastrophe insurance. The damage ratios are the expected costs to restore a building of a given damage grade, expressed in terms of a fraction of the cost of reconstructing a completely collapsed house. The damage ratios are reported in Table 2. I used the distribution of damage grade for each MSK-intensity to calculate expected damage cost. For example, at MSK-intensity 7, 10 percent of adobe houses suffer damage grade 1, 35 percent damage grade 2, 50 percent damage grade 3, and 5 percent damage grade 4. Using Table 3, the expected damage ratio for MSK-intensity 7 is $0.10 * 0.02 + 0.35 * 0.02 + 0.50 * 0.10 + 0.05 * 0.50 = 0.084$. To translate this into USD, I multiply by the cost of reconstructing a rural adobe house in Chile as reported in Comerio (2013) (USD $20,000$). These back-of-the-envelope calculations are for illustrative purposes only.

[2] Bommer, J., R. Spence, M. Erdik, S. Tabuchi, N. Aydinoglu, E. Booth, D. del Re, and O. Peterken (2002): "Development of an earthquake loss model for Turkisj catastrophe insurance," *Journal of Seismology, 6(3),* 431-446.

Table 2: Assumed damage ratios (Bommer at al. 2002)

Damage Grade	**Damage Ratio**
G0	0%
G1 or G2	2%
G3	10%
G4	50%
G5	100%

Table 3: Damage grade and damage ratios for the two types of constructions in my sample

MSK Intensity	**Adobe**		**Unreinforced masonry**	
	DG	**N (%)**	**DG**	**N (%)**
V	G1	5	G0	100
	G0	95		
VI	G2	5	G1	5
	G1	50	G0	95
	G0	45		
VII	G4	5	G2	50
	G3	50	G1	35
	G2	35	G0	15
	G1	10		
VIII	G5	5	G4	5
	G4	50	G3	50
	G3	35	G2	35
	G2	10	G1	10
IX	G5	50	G5	5
	G4	35	G4	50
	G3	15	G3	35
			G2	10
X	G5	75	G5	50
	G4	25	G4	35
			G3	15
XI	G5	100	G5	75
			G4	25
XII	G5	100	G5	100

MSK Intensity	Cities
≥ VIII	Peralillo (1), Pumanque (2), Licantén (3), Curepto (4), Constitución (5), Talca (6), Cauquenes (7), Parral (8)
VII ½	Navidad (9), Doñihue (10), Coínco (11), Esperanza (12), Coltauco (13), Pichidegua (14), Población (15), Santa Cruz (16), Chépica (17), Lolol (18), Curicó (19), Gualleco (20), Batuco (21), Concepción (22)
VII	El Convento (23), San Enrique (24), La Boca (25), Matanza (26), Rengo (27), Litueche (28), Machalí (29), La Estrella (30), Peumo (31), San Vicente de Tagua Tagua (32), Las Pataguas (33), Teno (34), Rauco (35), Hualañe (36), Molina (37), Cumpeo (38), Pencahue (39), Bobadilla (40), Empedrado (41), Chanco (42), Retiro (43), Cobquecura (44), Quirihue (45), Ninhue (46), San Carlos (47), Quillón (48), Bulnes (49), Penco (50), Tomé (51), Florida (52), Lota (53), Santiago (106)
VI ½	Pomaire (54), Talagante (55), El Monte (56), Melipilla (57), San Pedro (58), Rapel (59), Rancagua (60), San José (61), Marchigue (62), San Fernando (63), Paredones (64), Nancagua (65), La Huerta (66), Pelarco (67), San Clemente (68), San Javier (69), Villa Alegre (70), Linares (71), Longaví (72), Coelemu (73), San Nicolás (74), Chillán (75), Ñipas (76), Cabrero (77), Los Ángeles (78), Angol (79)
VI	San Antonio (80), Codegua (81), Las Cabras (82), Requínoa (83), Chimbarongo (84), Romeral (85), Yerbas Buenas (86), Trehuaco (87), San Ignacio (88), General Cruz (89), Pemuco (90), Monte Aguila (91), Yumbel (92), Yungay (93), Arauco (94), La Laja (95), Curanilahue (96), Nacimiento (97), Lebu (98), Los Álamos (99), Tres Pinos (100), Valparaíso (107), Viña del Mar (108)
V	Renaico (101), Cañete (102), Los Sauces (103), Contulmo (104), Purén (105), Los Vilos, Illapel, Salamanca

Figure 1: Towns sampled in Astroza, Rui and Astroza (2012). The number in parenthesis is the town identifier used in the isoseismal map reported in their paper. Towns are classified according to their MSK intensity, as determined by direct observation by structural engineers. *Source:* Astroza, Rui and Astroza (2012).

3 Testing Monotonicity of $h(c)$, details

Consider the i.i.d. sample $\{c_i, -y_i\}_{1 \leq i \leq n_l}$, where n_l is the size of the l^{th} classroom category.[3] Let c_i and c_j be a pair of observations for c. The test function within each category l is defined as:

$$b(s) = b(\{c_i, -y_i\}, s) = \frac{1}{2} \sum_{1 \leq i,j \leq n} (-y_i + y_j) sign(c_j - c_i) Q(c_i, c_j, s)$$

where I dropped the l subscript for convenience, and where $Q(c_i, c_j, s)$ is a weighting function indexed by $s \in S$. To each s corresponds a choice of point c and bandwidth h for the following specification of the weighting function:

$$Q(c_1, c_2, (c, h)) = K\left(\frac{c_1 - c}{k}\right) K\left(\frac{c_2 - c}{k}\right)$$

where $K(u) = 0.75(1 - u^2)$ if $-1 < u < 1$, and $= 0$ otherwise, and where $k = \frac{1}{2} n_l^{-\frac{1}{5}}$.[4] I let c take on 100 values, which identify equally spaced points going from the smallest to the largest observed value of c_i in the population. As a result, there are 100 weighting functions for each classroom category l.

Conditional on $\{c_i\}$, the variance of $b(s)$ is given by:

$$V(s) = V(\{c_i\}, \{\sigma_i\}, s) = \sum_{1 \leq i \leq n} \sigma_i^2 \left(\sum_{1 \leq j \leq n} sign(c_j - c_i) Q(c_i, c_j, s) \right)^2 \tag{1}$$

where $\sigma_i = \left(E[\epsilon_i^2 | c_i]\right)^{\frac{1}{2}}$ and $\epsilon_i = -y_i - (-h(c_i))$. Following Chetverikov (2013), I use the residual $\hat{\epsilon_i} = -y_i - (-h(c_i))$ as an estimator for σ_i, and obtain the estimated conditional variance of $b(s)$ by substituting σ_i^2 with $\hat{\sigma}_i^2$ in equation 1. The test statistic is given by:

$$T = T(\{c_i, -y_i\}, \{\hat{\sigma}_i\}, S) = \max_{s \in S} \frac{b(\{c_i, -y_i\}, s)}{\sqrt{\hat{V}(\{c_i\}, \{\hat{\sigma}_i\}, s)}}.$$

Large values of T indicate that the null hypothesis that $-h$ is increasing is violated.

To simulate the critical values, I adopt the plug-in approach. The goal is to obtain a test of level α. Let $\{\xi_i\}$ be a sequence of B independent $N(0, 1)$ random variables that are independent of the data. Let $-y_{i,b}^* = \hat{\sigma}_i \xi_{i,b}$ for each $b = 1, B$ and $i = 1, n$, where $\hat{\sigma}_i = \hat{\epsilon}_i$. For each $b = 1, B$, calculate the value T_b^* of the test statistic using the sample $\{c_i, -y_{i,b}^*\}_{i=1}^n$. The plug-in critical value $c_{1-\alpha}$ is the $(1 - \alpha)$ sample quantile of $\{T_b^*\}_{b=1}^B$.

[3] y_i is replaced by $-y_i$, and h will be replaced by $-h$, because this procedure tests that $-h$ is increasing, which is equivalent to testing that h is decreasing.

[4] This is the value for h recommended in Ghosal, Sen, and Van Der Vaart (2000).

Table 4: Values of test statistics and critical values for test of monotonicity at the $\alpha = 0.10$ significance level, by classroom category. 8 randomly selected categories.

	Mathematics		Spanish	
Classroom Category	Test statistic	Critical Value	Test statistic	Critical Value
Pre-earthquake classrooms				
1	2.2874460E-02	4.60e+19	4.0707965E-03	1.05e+19
2	6.2840671E-04	1.08e+19	1.6759724E-03	7.75e+18
3	3.6209350E-04	4.98e+18	1.0020613E-03	1.79e+19
4	3.9056635E-03	1.92e+19	2.2328943E-03	1.97e+19
Post-earthquake classrooms				
5	1.0598215E-03	6.01e+18	3.8213478E-04	1.63e+19
6	2.7184933E-03	1.41e+19	1.1514544E-03	1.32e+19
7	4.1919011E-03	4.22e+19	1.3525186E-03	1.19e+19
8	1.7282768E-03	1.22e+19	3.4069275E-03	1.42e+19

In all classroom categories, the test statistic is below the critical value. Therefore, the null hypothesis that $h(c)$ is monotonically decreasing is not rejected.