NATURAL DISASTERS AND DIFFERENTIAL HOUSEHOLD EFFECTS: EVIDENCE FROM THE MAY 2006 JAVA EARTHQUAKE ECON 220F, PROF. CARSON, SPRING 2010

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ABSTRACT. Devastating natural disasters occur many times each year all around the world, leaving death, trauma, and destruction of private and public capital. These effects obtain even in countries with sophisticated prediction and construction technology, and all the more in less developed countries. Case studies and anecdotal evidence often indicate a divergent effect: within an affected area, the poorest victims end up much worse off relative to their richer neighbors. They suggest both direct mechanisms that lead to differential immediate damage and indirect mechanisms during the recovery period. I look at evidence from a panel household survey in Indonesia to test for differential effects of the May 2006 earthquake in Java. My results support the direct mechanism story, and they show signs of certain indirect mechanisms but without statistical significance.

1. INTRODUCTION

Natural disasters happen. And, as with much of nature, the distribution of magnitude has a noteworthy upper tail, with extremely powerful events occurring regularly. Even with technology for prediction and reinforced buildings and structures, countries face destruction and trauma every year, and the impact is far greater in countries without such technology. Even just this year (2010, through May), we have witnessed the January 12 earthquake in Haiti, the February 27 earthquake in Chile, and the April 14 earthquake in China, to name three of devastating proportion, along with massive flooding and mudslides in January and April in Brazil and other types of natural disasters in yet other countries. The effects of death and trauma will persist regardless of the disaster recovery aid provided, and, especially in developing countries, even the private economic impact on victims can linger. The main focus of this paper is if that lingering is significantly different for those who were already at the poor end of the distribution before the disaster.

In economics, natural disasters are still relatively sparsely studied. Within that, most studies have looked at economic variables aggregated over regions or countries. Some of the papers in this area include work on disaster frequency and long-run growth (Cuaresma, Hlouskova & Obersteiner, 2008; Skidmore & Toya, 2002); international financial flows (Yang, 2008a); secondary schooling and (geological) disaster frequency (Cuaresma, 2009);

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aggregate economic effects of Hurricane Hugo (Guimaraes, Hefner & Woodward, 1993); (average) income and disaster damage risk (Kellenberg & Mobarak, 2008); and differential effects of disasters by country characteristics (Noy, 2009). There have also been studies of mental health effects (Frankenberg *et al.*, 2008; de Mel, McKenzie & Woodruff, 2008) from the 2004 Indian Ocean tsunami (Indonesia, Sri Lanka). Yang (2008b) examined migration as risk-coping, applied to earthquakes in El Salvador.

There has been some sparse qualitative/preliminary evidence outside of economics (Bates, 1963; Cochrane, 1975; Haas, Kates & Bowden, 1977; Geipel, 1982) for differential impacts of natural disasters for the richer portion of the affected population compared with the poorer. These case studies suggest that divergent effects may come from both the initial, direct effect of a disaster (poorer people live in less sturdy buildings, for instance, and tend to have less insurance) as well as indirect effects from how recovery aid is targeted/claimed, the impact of personal debt, mobility, post-recovery rent, and other factors.

Motivated by the above, the following analysis attempts to address the question: within an area struck by a natural disaster, are richer residents affected differently than their poorer neighbors? Specifically, if so, is this due to a differential direct effect? (*E.g.*, if poor people live in less structurally sound houses.) Or does this difference arise during the recovery period? (*E.g.*, if richer victims are better able to obtain government aid.) I look for empirical evidence speaking to these questions from the May 2006 earthquake in Indonesia. I hope to develop empirical methods that would be easily applied to data from other countries, so that in time a more comprehensive body of evidence could be gathered to inform policy.

2. Data

2.1. **Setting.**
The event I study is the earthquake that struck Indonesia on May 27, 2006, at 5:54am local time. Specifically, the epicenter was in the district (*kabupaten*) of Bantul in the Special Region (same level in hierarchy as province) of Yogyakarta. The earthquake affected all five districts in Yogyakarta, including the city of Yogyakarta, as well as some neighboring provinces near the border with Yogyakarta. Yogyakarta is relatively homogenous religiously and ethnically, over 90% Muslim and 97% Javanese.

The magnitude 6.3 earthquake had a large impact. "[T]he Yogyakarta earthquake claimed more than 5,000 lives, injured almost 40,000 others and left an estimated 1.5 million homeless in May 2006. Long after the cleanup, the economic devastation remains" (*Jakarta Globe*, Jan. 11, 2010). Though it was quite large, similar or worse earthquakes have already occurred multiple times this year (to date) alone, so it is a representative event in terms of magnitude.

2.2. **Sample.**
The sample comes from the Indonesia Family Life Survey (IFLS), provided for public use by RAND. I used observations from the third and fourth waves of the panel, IFLS3 in 2000 and IFLS4 in 2007/2008. It is, as the name suggests, a survey of households,

FIGURE 1. Map of earthquake epicenter, 27 May 2006, 5:54am local time, from USAID, `http://www.usaid.gov/locations/asia_near_east/java_quake/pdf/javaeq_map01_053006.pdf`

TABLE 1. Number of households in basic categories

Affected by May 2006 Quake	Yogya. Prov. (2007) 0	1	Total
0	5155	39	5194
1	7	188	195
Total	5162	227	5389

where respondents answer (as best they can) for the entire household for most questions (expenditure, assets, *etc.*). Figure 4 shows the provinces covered by the survey; notably, Yogyakarta and in fact all other provinces on Java are included.

Table 1 shows the number of households in the sample. There are 5,389 total households (each with data from 2000 and 2007), including 195 households that reported being affected by the May 2006 earthquake "severe[ly] enough to cause death or major injuries of a household member, cause direct financial loss to the household, or cause household member to relocate," as the English translation of the survey instrument puts it. Of those 195, 188 were in Yogyakarta, of 227 total in Yogyakarta. Unfortunately, this leaves only 39 households in Yogyakarta not reporting such effects, so these 39 households (compared

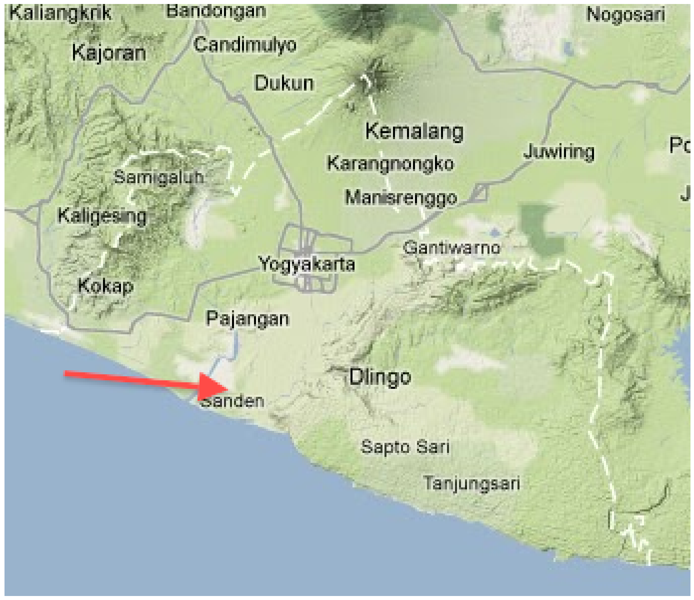

FIGURE 2. Map of entire Yogyakarta province (Special Region), with arrow to epicenter, from Google Maps

with the 188) generate the variation analyzed for differential direct effects. For difference-in-difference estimation, other provinces can be used for the "control" group.

2.3. **Description.** All the data come from household survey responses. The primary variables I look at are:

- Expenditure: this covers a comprehensive range of categories, including food[1], utilities, transportation, entertainment, education[2], taxes, medical costs, durables, *etc.* This does not include estimates of self-produced consumption or in-kind assistance, which are included in the survey but not in the analysis here.
- Assets: farm assets, non-farm business assets, and non-business (household) assets, including land, house, appliances, vehicles, *etc.*
- Earthquake effects: any (see above), business assets lost, non-business assets lost, degree of house damage (none, light, heavy, total), government/NGO assistance, *etc.*

I have converted all amounts to annual amounts (some survey questions asked for weekly or monthly) and used the International Monetary Fund's Consumer Price Index for Indonesia to adjust for inflation, and converted to year 2000 purchasing power parity (PPP) dollars,

[1]Includes food, beverages, tobacco, alcohol, and prepared food.

[2]Includes tuition, PTA fees, registration, exams, uniforms, transportation, *etc.*

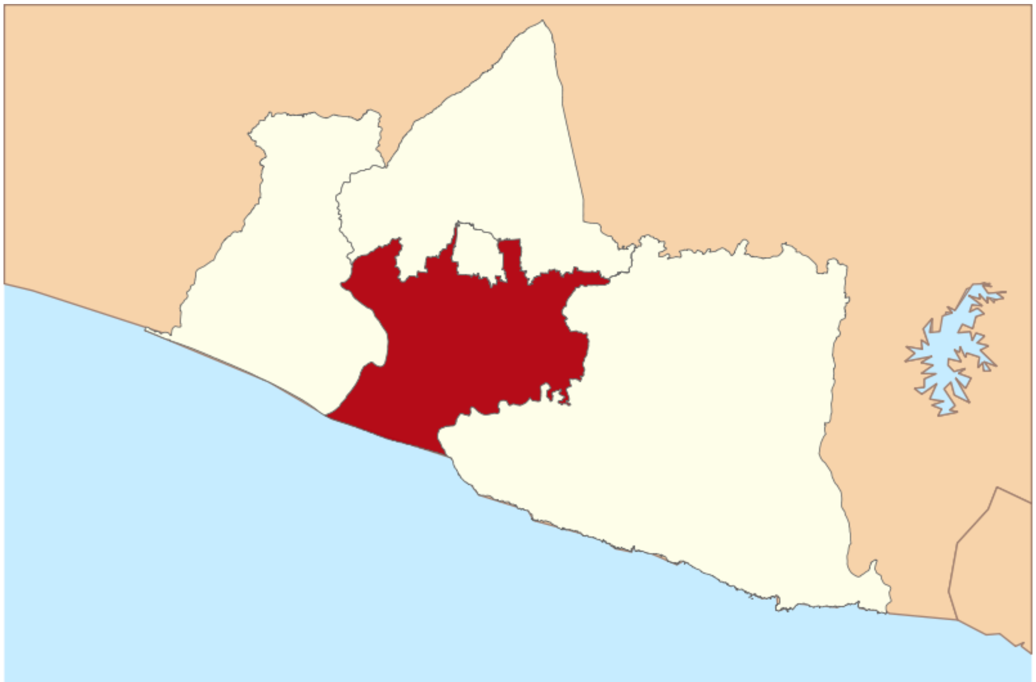

FIGURE 3. Map of Bantul (in red), Yogyakarta. Of 195 households reporting effects of the earthquake in my sample, 149 are located in Bantul. Image from `http://id.wikipedia.org/wiki/Berkas:Lokasi_DIY_Kabupaten_Bantul.svg`

FIGURE 4. Map of IFLS coverage, from RAND, `http://www.rand.org/labor/FLS/IFLS/`

Table 2. Mean household expenditure and assets

per HH		Quake-affected	Rest of Yogya.	Outside Yogya.
	HH size (2000)	3.58	4.28	3.76
	HH size (2007)	5.15	5.67	5.64
Expenses	Total (2000)	2963	7972	3454
	Total (2007)	8840	2169	6705
	Food (2000)	1524	2762	2041
	Food (2007)	2076	1989	2642
Assets	Farm (2000)	18,338	9882	9028
	Farm (2007)	15,177	9161	10,179
	Non-farm Bus. (2000)	3524	21,174	3781
	Non-farm Bus. (2007)	4404	7700	3907
	Non-bus. (2000)	18,008	27,416	13,548
	Non-bus. (2007)	20,781	18,410	17,083
	N	195	39	5155

Table 3. Mean per capita expenditure and assets

per capita		Quake-affected	Rest of Yogya.	Outside Yogya.
	HH size (2000)	3.58	4.28	3.76
	HH size (2007)	5.15	5.67	5.64
Expenses	Total (2000)	827	1862	918
	Total (2007)	1715	383	1188
	Food (2000)	425	645	542
	Food (2007)	403	351	468
Assets	Farm (2000)	5116	2308	2400
	Farm (2007)	2945	1617	1804
	Non-farm Bus. (2000)	983	4945	1005
	Non-farm Bus. (2007)	855	1359	692
	Non-bus. (2000)	5024	6403	3601
	Non-bus. (2007)	4032	3249	3028
	N	195	39	5155

for more intuitive interpretation (for those more familiar with dollars than rupiah). When per capita amounts are discussed, household totals are divided by the number of household members at the time of the survey. A useful refinement, especially when analyzing food expenditure, would be to adjust for adults versus children.

Table 2 shows means for household size, expenditure, and assets. Table 3 shows the same table but with per capita[3] amounts. (Note that the increasing household size is potentially an artifact of filtering out households that split into two between 2000 and 2007; since household size is potentially affected by the earthquake, it would be better to find a way to include such split households if possible.) As a sanity check, the World Bank in 2005 reported a per capita food expenditure of 607 PPP dollars for Indonesia. For provinces outside of Yogyakarta, I found per capita food expenditure of 542 and 468 in 2000 and 2007, respectively, measured in year 2000 PPP dollars. This seems reasonably close, especially considering some inflation between 2000 and 2005. The most striking result from Table 2 is that total expenditure goes up dramatically for households affected by the earthquake and goes down even more dramatically for households in Yogyakarta not reporting being affected by the earthquake. Two immediate and less interesting explanations are that the earthquake-affected household size increased much more and that total expenditure may be inflated by government assistance for rebuilding a destroyed house and such projects. If we look instead at per capita food expenditure in Table 3, we see very similar values for the affected households, but still a puzzlingly dramatic drop for other households in Yogyakarta, suggesting that the earthquake is somehow worse for those not directly impacted.

From the assets rows, it appears that the affected households were more agrarian than those not reporting direct effects, as the affected households had over twice the per capita farm assets before the earthquake but five times fewer non-farm business assets beforehand. Affected households have fewer total assets before, but unaffected households' total assets drop to a point even below the affected households' total assets surveyed after the earthquake—also not an expected pattern.

Table 4 presents means of variables capturing earthquake loss and assistance. Of note, the non-business assets lost mean of 3502 is substantial (recall that these are adjusted to year 2000 PPP dollars, and compare to the base from Table 2), and assistance is substantial but still significantly less at 2186; and yet the non-business assets reported increases from 18,008 to 20,781 as shown in Table 2. Exaggerated losses alone can't explain this, since even if the true losses were zero, the 2000 to 2007 gap is not even covered by the average assistance amount; that explanation also fails to account for the drop of over 9000 for unaffected households in Yogyakarta. Also of note in Table 4 is that 65 percent of households affected report some house damage, and 86% report being homeless or in temporary housing at some point. This does, of course, beg the question of why the 21% of affected households reported no house damage but having to live in temporary housing, and this is not a trivial discrepancy. There is no possible explanation for this aside from "measurement error" of some sort, as far as my imagination can tell, but I shall press on nonetheless.

[3] That is, Table 2 values divided by the average household sizes appearing in the first two rows of that table. So this is the total expenditure divided by the total number of people, as opposed to per capita values averaged with the household being the unit of observation.

Table 4. Means of variables capturing earthquake loss and assistance

per HH	N=195	Mean
	Bus. Assets Lost	172[a]
	Non-bus. Assets Lost	3502[b]
	Injury/Death Cost[c]	3381[d]
	Assistance[e]	2186[f]
	Death?	0.04
	Injury/Illness?	0.08
	Light House Damage?	0.48
	Heavy House Damage?	0.17
	Repair/Rebuild?	0.94
	Homeless/Temp. Housing?	0.86

[a]Or 818 among only the 41 non-zero values.
[b]Or 3994 among only the 171 non-zero values.
[c]Out-of-pocket medical or funeral cost due to earthquake.
[d]Or 82,412 among only the eight non-zero values.
[e]From anywhere except friends and family; incl. domestic and foreign, government, NGO, firm.
[f]Or 2522 among only the 169 non-zero values.

3. Analysis and Results

3.1. **Direct Effects.** The most likely mechanism through which an earthquake would have a differential effect on poorer victims involves differential sturdiness of houses. As motivated earlier, perhaps poorer households cannot afford the proper materials to build safer houses, or perhaps they are not informed of best practices for building houses in earthquake prone territory. A variety of sources confirm the importance of structural integrity of houses and its role in the damage from the May 2006 Java earthquake:

> This is a disaster-prone area and if people don't build back better the houses will fall down again, and we'll end up back here again. (David Hodgkin, UN Development Program, re: more recent quake in Indonesia, quoted in the *Jakarta Globe*, Dec. 1, 2009)

> "It's important for people to be aware that how a house is constructed makes a big difference when an earthquake hits," he said, stressing that a well-structured house would save lives and reduce the damage inside houses. (Edie Prihantoro, State Ministry of Research and Technology, quoted in the *Jakarta Globe*, Sept. 4, 2009)

Table 5. Correlation of pre-earthquake expenditure with various measures of direct damage

	Quake-affected (1)	Any Damage (2)	Heavy Damage (3)	Temp/ Homeless (4)	%Assets Lost (5)
$\text{Ln}(1+\text{Exp}_{2000})$	-0.08*	-0.08*	-0.08*	-0.10*	-0.04*
	(0.025)	(0.036)	(0.029)	(0.028)	(0.018)
R^2	0.04	0.03	0.04	0.05	0.03
N	253	191	191	253	195

Sample: subdistricts with at least one household reporting having been affected by the earthquake for (1) and (4); affected households only for (2), (3), and (5).
* Significant at 5 percent.

Table 6. Correlation of log pre-earthquake assets with log assets lost, testing for coefficient of unity

Ln(1+AssetsLost)	Coeff.	SE	p-val (coeff=1)
$\text{Ln}(1+\text{Assets}_{2000})$	0.69	0.186	0.09
R^2	0.07		
N	195		

Note: "Assets" are non-business assets only here.

> Most homes in the area were built with low-quality materials without structural frames and reinforcing pillars. Many deaths and injuries occurred when buildings and walls collapsed. (Wikipedia)

> The father of four, who eked out a living making traditional daggers known as *kris*, said the Rp 15 million ($1,600) he received in aid was only sufficient to build a semipermanent house, let alone replace his tools that were destroyed when his home collapsed. (*Jakarta Globe*, Jan. 11, 2010, re: May 2006 quake)

> In Yogyakarta, many women lost livestock and their small businesses. (Cosgrave, 2008)

These sources suggest that there is a big difference between how a well-built, high-quality house responds to an earthquake and how a poorly-built, low-quality house responds, and that the measurable effect of this could extend beyond house damage to asset loss as well.

What do the data have to say about this—is lower pre-earthquake log expenditure correlated with more damage? The results of Table 5 suggest that it indeed is, robust to a variety of measures of damage (any loss, house damage, asset loss). Note that the independent variable is log expenditure, and the dependent variables are either indicators or a percentage, so the interpretation of the coefficient, for example, when regressing reported "heavy damage" to a house on log pre-earthquake expenditure is that a 1 percent increase in expenditure corresponds to a 0.08 percent decrease in the probability of heavy house damage. This seems small, though of course 100 percent higher expenditure (*i.e.*, double, which is a reasonable comparison) would mean 6 percent lower probability of heavy house damage; and keep in mind that measurement error would (if classical) lead to estimates closer to zero than the true effect. The coefficients are each significant at the five percent level.

However, it is quite possible that spatial correlation would lessen or even erase this result. Without informing the estimation with knowledge of household locations, it is possible that poorer neighborhoods happened to be closer to the epicenter, where damage was higher. As an illustration, imagine that everyone living in Bantul district (containing the epicenter) was poorer than everyone living in the city of Yogyakarta (north of Bantul). Damage will be correlated with proximity to the epicenter, as a consequence of physics alone; but since proximity to epicenter is correlated negatively with expenditure levels, we falsely conclude that there is a meaningful correlation between damage and expenditure. Given the earlier evidence that affected households were more agrarian than others in Yogyakarta, this may well be the true story. At a minimum, village-level location (and distance from epicenter) would need to be added to attempt to control for the fact that both damage and expenditure levels are spatially correlated.

Table 6 also suggests a negative correlation between initial economic wellbeing and damage, but is similarly vulnerable to spatial correlation. A coefficient of unity would imply that a one percent increase in pre-earthquake asset level is correlated with a one percent increase in assets lost in the earthquake, *i.e.*, the same percentage of assets are lost irrespective of initial asset levels. However, the coefficient is 0.69, so a one percent increase in initial assets is correlated with only a 0.69 percent higher loss: as the initial asset level increases, the percentage of assets lost decreases. This coefficient is only significant at a 10 percent level. A nonparametric estimation of this relationship may be even more insightful, as it is likely nonlinear (which may contribute to a lower p-value in the linear regression, too).

3.2. **Indirect Effects.**

3.2.1. *Assistance.* One of the many suggested indirect mechanisms that may lead to divergence of expenditure levels is wealthier victims being more adept at obtaining financial assistance from the government or other organizations. This mechanism is articulated well by one victim of the 2006 earthquake:

Table 7. Correlation of pre-earthquake log expenditure with whether a household received assistance and the amount of that assistance, among all 195 affected households or only the 127 reporting house damage

			If reported house damage	
	Rec'd Assistance?	Amount	Rec'd Assistance?	Amount
	(1)	(2)	(3)	(4)
$\text{Ln}(1+\text{Exp}_{2000})$	-0.02	-0.56	-0.03	-0.41
	(0.026)	(0.419)	(0.024)	(0.403)
R^2	0.00	0.01	0.01	0.01
N	195	195	127	127

Note: "Assets" are non-business assets only here.

"I am only one of the little people, I do not know how to request aid." (Jimah, snack seller at Royal Cemetery whose house collapsed, quoted in the *Jakarta Globe*, Jan. 11, 2010; before quake, made Rp 1 million per month)

The question put to data was: is lower pre-earthquake expenditure correlated with lower assistance received, controlling for the degree of damage sustained (as a proxy for earthquake-induced need)? The answer from Table 7 is no. If anything, lower pre-earthquake expenditure is associated with a higher probability of receiving assistance, whether conditioning on household damage or not, but none of the coefficients are close to being statistically significant. Additionally, it is interesting that the woman quoted above considers herself one of the "little people" when she seems to fall above the median, comparing how much she said she made before the earthquake to the distribution of pre-earthquake expenditure in the data sample for households receiving assistance (assuming her expenditure equaled how much she made and that nobody else in her house made any money).

3.2.2. *Household Not Directly Damaged.* What effect on expenditure do we see on households not reporting being directly affected by the earthquake? There are at least two good reasons that we would see a significant decrease in expenditure for households in the area even if they were not directly impacted. First, there may be damage to local infrastructure: "Not only were his tools and inventory destroyed, but so was the souvenir market where he sold his goods" (*Jakarta Globe*, Jan. 11, 2010). Second, there may be an overall local economic downturn: "In fact, many silversmiths who once worked in the back rooms of Yogyakarta's silver stores in Kota Gede were forced to return to their villages jobless after the quake" (*Jakarta Globe*, Feb. 9, 2010). Tourism may fall off abruptly, household loss may lower local demand for many goods, and other indirect effects may obtain.

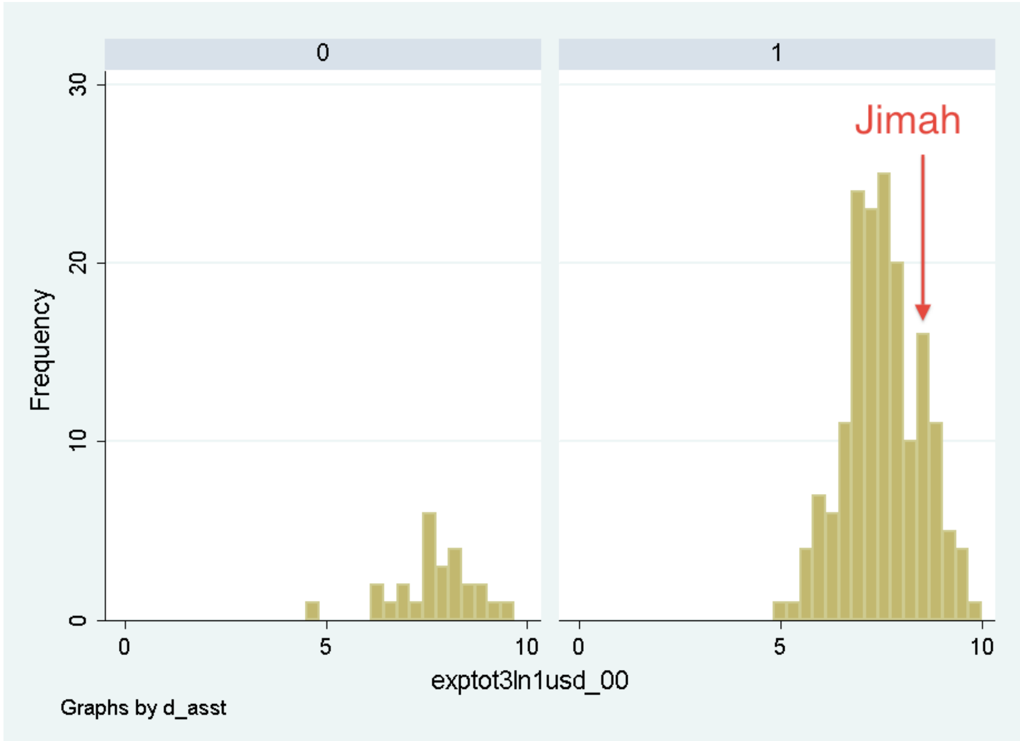

FIGURE 5. Log expenditure in year 2000 by whether received assistance or not.

I estimated a difference-in-difference model with the following specification:

$$\begin{aligned}(1)\qquad \ln(Y_{ist}) = \alpha + \delta_1 1\{s = \text{AFFECTED AREA}\} \\ + \delta_2 1\{t = 2007\} + \delta_3 1\{s = \text{AFFECTED AREA}\} * 1\{t = 2007\} + \epsilon_{ist}\end{aligned}$$

where Y_{ist} is some measure of expenditure for household i in state $s \in$ {AFFECTED AREA, ELSEWHERE} at time $t \in \{2000, 2007\}$, "AFFECTED AREA" indicates being in an area with at least one household having reported earthquake effects (but no affected households are present in the regression sample), "ELSEWHERE" indicates areas where no households reported earthquake effects, and $1\{\cdot\}$ is the indicator function, 1 if true and 0 if false.

I estimated equation (1) with OLS and simultaneous quantile regression with bootstrapped standard errors[4]. I first used unaffected households in Yogyakarta as the "treatment"

[4]Stata: `sqreg`, simultaneous quantile regression with bootstrapped standard errors, with which tests for differences in coefficients across quantiles may be performed.

TABLE 8. Comparing (reported unaffected households located in Yogyakarta) with (unaffected households in other provinces). The dependent variable is log per capita food expenditure.

	OLS (1)	q05 (2)	q20 (3)	q80 (4)	q95 (5)
1{s=YOGYA}	-0.03	-0.32	-0.39	0.02	-0.14
	(0.155)	(0.215)	(0.302)	(0.240)	(1.178)
1{t=2007}	-0.25	-0.25	-0.24	-0.28	-0.34
	(0.023)	(0.057)	(0.028)	(0.023)	(0.045)
1{s and t}	-0.03	-0.03	0.30	0.15	0.23
	(0.255)	(0.458)	(0.509)	(0.389)	(1.183)
(Pseudo) R^2	0.02	0.01	0.01	0.01	0.00
N	7283	7283	7283	7283	7283

Note: standard errors, in parentheses, are bootstrapped with 200 replications.

TABLE 9. Comparing (reported unaffected households located in districts with at least one affected household) with (unaffected households in other districts). The dependent variable is log per capita total expenditure.

	OLS (1)	q05 (2)	q20 (3)	q80 (4)	q95 (5)
1{s=AffdDist}	0.15	-0.17	-0.15	0.25	0.64
	(0.129)	(0.310)	(0.168)	(0.174)	(0.723)
1{t=2007}	-0.25	-0.34	-0.27	-0.26	-0.14
	(0.023)	(0.055)	(0.028)	(0.031)	(0.078)
1{s and t}	-0.14	0.28	0.18	0.00	-0.46
	(0.204)	(0.450)	(0.254)	(0.287)	(0.808)
(Pseudo) R^2	0.02	0.01	0.01	0.01	0.00
N	7317	7317	7317	7317	7317

Note: standard errors, in parentheses, are bootstrapped with 200 replications.

group (Table 8) and then unaffected households in any district (the level just smaller than province) with at least one affected household as the treatment group (Table 9). Note that the coefficient of interest, δ_3 in equation (1), is in the row 1{s and t}. None of the results are statistically significant, but there is a striking pattern in the latter table across the quantiles, decreasing from 0.28 to 0.18 to 0.00 to -0.46 starting at the 0.05 quantile and then the 0.20, 0.80, and 0.95 quantiles, respectively. Note that this would imply a convergent effect: the top quantile of expenditure shows the most negative effect on expenditure while the bottom quantile has the most positive. There are, as usual, stories

Table 10. For Yogyakarta, mean per capita total and food-only expenditure before and after earthquake, with number of observations in parentheses

	Reported quake-affected	Did not
Exp_{2000}/HHsz	780 (188)	4873 (39)
Exp_{2007}/HHsz	1864 (188)	867 (23)
$Food_{2000}$/HHsz	427 (188)	1178 (39)
$Food_{2007}$/HHsz	431 (188)	469 (23)

Note: as before, expenditure is inflation- and PPP-adjusted. HHsz is household size.

that could support either direction, but given the lack of statistical significance, I withhold a firm conclusion.

3.3. **Overall Net Effects.**

> "The poorest of the poor may never recover." (David Hodgkin, quoted in the *Jakarta Globe*, Dec. 1, 2009)

Since I was unable to test every possible individual mechanism through which divergence may appear, I ran a difference in difference model to examine the overall net changes in expenditure for those affected by the earthquake. While it is instructive to look at means, I focus more on the results from estimating effects at upper and lower quantiles to test whether the earthquake did actually have a significantly more devastating impact on the "poorest of the poor" and to get an initial quantitative estimate of that difference.

First, I present a table of means (Table 10). Again, it is puzzling that expenditure (total and food alike) falls off so dramatically for the households not reporting being affected by the earthquake. The final levels are still plausible, though, since they are quite similar to (slightly above) the levels of the earthquake-affected households in 2000. Nonetheless, the puzzle remains why "unaffected" households are seemingly so much worse off, and this motivates running a difference-in-difference using households outside Yogyakarta for the control group, instead of only the "unaffected" Yogyakarta households.

Second, using a difference-in-difference framework, what was the overall net effect of the earthquake on expenditure as surveyed a year after[5]? Further, does this effect differ significantly by expenditure quantile? The specification I ran was:

$$\ln(Y_{ist}) = \alpha + \delta_1 1\{s = \text{QUAKE}\} + \delta_2 1\{t = 2007\} + \delta_3 1\{s = \text{QUAKE}\} * 1\{t = 2007\} + \epsilon_{ist} \quad (2)$$

where Y_{ist} is some measure of expenditure for household i in state $s \in$ {QUAKE, ELSEWHERE } at time $t \in \{2000, 2007\}$, "QUAKE" indicates having reported being affected directly by the earthquake[6], "ELSEWHERE" may be restricted to Yogyakarta or certain other control province(s), and $1\{\cdot\}$ is the indicator function, 1 if true and 0 if false.

I estimated equation (2) with OLS and simultaneous quantile regression with bootstrapped standard errors[7]. I first used unaffected households in Yogyakarta as the control group (Table 11), and then households in the province of East Java as the control group (Table 12). The tables presented both use total per capita expenditure. I also ran per capita food[8] expenditure as the dependent variable, but no discernible pattern (or significance of coefficients) arose.

The coefficient of interest, δ_3 in equation (2), is in the row for 1{s and t} in the tables. In Table 11, there is a striking increasing pattern: the coefficient is quite negative at the 0.05 quantile, quite positive at the 0.95 quantile, and increasing in between, also. Recall that since the dependent variable is log expenditure, a coefficient of -0.44 is interpreted as a 44% decline in expenditure associated with the earthquake, while 0.91 is a 91% increase in expenditure. This difference has a large economic significance. Unfortunately, the standard errors are also quite large here. None of the individual coefficients of interest are statistically significant, and testing for equality of the coefficient of interest at the 0.05 and 0.95 quantiles yields a p-value of 0.49 even though the point estimates are far apart.

In Table 12, the sample size is larger and the control group is cleaner (another province altogether). A similar pattern arises in the coefficient of interest, and there is a move toward statistical significance. Now the test for equality of the coefficient of interest at the 0.05 and 0.95 quantile gives a p-value of 0.08, significant at a 10% level if not the more

[5]Note that the survey was performed over many months in 2007 and 2008, with some expenditure questions stretching back a year but some, like food, only the past week. Thus food expenditure captures the point around a year and a half after the earthquake hit, when both direct and indirect mechanisms would have started taking effect.

[6]Affected "severe[ly] enough to cause death or major injuries of a household member, cause direct financial loss to the household, or cause household member to relocate," as the English translation of the survey instrument puts it.

[7]Stata: `sqreg`, simultaneous quantile regression with bootstrapped standard errors, with which tests for differences in coefficients across quantiles may be performed.

[8]Again, "food" includes food, beverages, alcohol, tobacco, and prepared food.

Table 11. Quantile difference-in-difference for log total per capita expenditure. Control group: Yogyakarta households not reporting direct earthquake effect.

ln(Exp/HHsz)	q05 (1)	q20 (2)	q80 (3)	q95 (4)
1{s=QUAKE}	0.04	0.14	-0.52	-0.42
	(0.235)	(0.260)	(0.208)	(1.653)
1{t=2007}	-0.07	0.02	-0.19	-0.52
	(0.425)	(0.399)	(0.400)	(1.683)
1{s and t}	-0.44	-0.11	0.16	0.91
	(0.464)	(0.417)	(0.411)	(1.742)
(Pseudo) R^2	0.03	0.00	0.02	0.02
N	438	438	438	438

Note: standard errors bootstrapped with 120 replications. p-val=0.49 for test of equal 1{s and t} at 0.05 and 0.95 quantiles. HHsz is household size.

Table 12. Quantile difference-in-difference for log total per capita expenditure. Control group: households in East Java province.

ln(Exp/HHsz)	q05 (1)	q20 (2)	q80 (3)	q95 (4)
1{s=QUAKE}	-0.04	-0.07	-0.11	-0.26
	(0.175)	(0.083)	(0.093)	(0.126)
1{t=2007}	-0.36	-0.30	-0.24	-0.36
	(0.097)	(0.051)	(0.052)	(0.137)
1{s and t}	-0.15	0.26	0.20	0.72
	(0.289)	(0.161)	(0.133)	(0.414)
(Pseudo) R^2	0.02	0.01	0.01	0.01
N	2168	2168	2168	2168

Note: standard errors bootstrapped with 120 replications. p-val=0.08 for test of equal 1{s and t} at 0.05 and 0.95 quantiles. HHsz is household size.

conventional 5% level. Unfortunately, further increasing the size of the control group (to all unaffected provinces) has no additional benefit to statistical significance at this point; most likely there would need to be additional treatment observations at this point to speak more definitively to this divergence in expenditure across quantiles of expenditure. Still, the results here suggest that these stories of divergence that have been told may indeed be quite visible in household level data, if data exist for enough affected households.

3.4. **Further Effects.**

3.4.1. *Induced Migration.* One indirect mechanism that did not appear to be part of the story here is induced migration. Put succinctly by a report from the Active Learning Network for Accountability and Performance in Humanitarian Action (ALNAP), "Population displacement was negligible in Yogyakarta" (Cosgrave, 2008). I examined the data to check: did households relocate differently after the earthquake depending on initial expenditure quantile? Of the 195 households reporting to be earthquake-affected, only 24 moved: seven within the same village, seven within the same district, nine within the same province, and one that moved to a different province. Results from a probit model (and linear probability model) for whether an affected household moved outside its year 2000 village showed no sign of dependence on expenditure, with p-values of 0.60 (in each model) for the coefficient on log per capita expenditure in 2000. Additionally, any of the 17 households that moved to a different village may have simply moved for another reason before the earthquake, in the period 2000-April 2006. Note that I only looked at the household level and did not look for individuals within a household migrating as did Yang (2008b) in El Salvador, so I am unable to comment on his findings.

3.4.2. *Future Work.* There remain many immediate directions for future work. In addition to carefully examining potential issues (or, improvements) related to spatial correlation and sample attrition/splitting, the picture of overall net effects is not complete without study of savings, debt, and income. The *Jakarta Globe* reports effects manifest in both savings and debt:

> Many families have used up their savings over the past months, setting back their life plans and ambitions. (*Jakarta Globe*, Dec. 1, 2009, re: Sep. 2, 2009 earthquake in West Java)
>
> Bejo said that to pay off his debt, he had to seek high-interest loans from other sources. "I am trapped by multiple loans now, as I have to pay high interest." (*Jakarta Globe*, Jan. 11, 2010, re: victim of May 2006 earthquake).

It is possible, especially if many families were near a (perceived) "subsistence" level of expenditure before the earthquake or if they had overly optimistic expectations of the post-earthquake local economy, that families would choose to continue the same level of expenditure but have to take out loans or draw down savings to finance it.

There may also be effects that are even more difficult to capture, especially in a developing country. As quoted in the *Jakarta Globe*, Dec. 1, 2009, David Hodgkin noted, "In Yogyakarta there are families that might have previously owned a 100- to 200-square-meter house before the [2006] quake that are currently living in a 50-square meter house and slowly extending." This could show up perfectly in the level of household assets, as respondents are asked to estimate the monetary value of their house and land, but at a minimum there is likely a high degree of measurement error. If this is all, though, we should only see attenuation bias, and reported effects will be lower bounds. Hopefully any of the more difficult-to-measure changes are highly correlated with the observable changes that can be estimated from data.

4. Conclusion

I examined a panel of household survey data in Indonesia to test theories that natural disasters adversely affect the poorest victims relatively more than richer victims. My results support the story that poorer victims suffer greater immediate damage, plausibly due to less-sturdy houses (from lack of knowledge of best building practices or lack of ability to purchase necessary materials). Initial results are less clear on indirect mechanisms; the data did not show anything regarding assistance or migration, while there were hints at divergence of overall expenditure levels over a year later but no statistical significance.

With respect to applying the analyses here to other natural disasters, in order to gather a body of evidence large enough to inform policy, it seems that to get the full picture, the data requirement is high. Indirect effects may show up in expenditure levels, or they may not but rather be hidden in savings level changes, and/or in debt levels (or even interest rates being paid). Even with direct effects, spatial correlation must be carefully accounted for in order to gain reasonable confidence about results. And of course no two disasters or aid responses are alike, but hopefully that variation can someday be leveraged to identify causal effects of response policy.

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