The Economic Silver Lining to the Human Catastrophe of a Natural Disaster:

The Causal Impact of the Indian Ocean Tsunami on Aceh's Long-Term Economic Development

Martin P. Heger

Outline

1. Talk a bit about natural disaster economics (theoretical & empirical links between shock and economic output)
2. Why Aceh is different
3. Research design – quasi experiment
4. Findings of creative destruction
5. Causal mechanisms
6. Conclusion
7. Mapping future research

My contributions

- Causal case for long-term creative destruction effects (increased long-term per capita output)
- Investigate the causal mechanisms
- Using flooding maps for impact analysis. The few studies using exogenous physical measures look mostly at hurricanes (using wind field models)
- Using local (spatial) data. Most studies use national data
- Extreme natural disasters need not lead to output reductions. Disaster aid worked. No excuse!

Extreme natural disasters have large adverse human consequences

- They kill, they hurt, they traumatize.
- E.g. Indian Ocean Tsunami (well studied):
  - 230,000 – 280,000 casualties (or missing)
  - Longitudinal Survey in Aceh, Indonesia before and after the Tsunami focusing on well-being (STAR)
    - Mental Health *(Frankenberg et al 2008)*
    - Fertility *(Nobles, Frankenberg, Thomas 2015)*
    - Demography *(Frankenberg, Laurito, Thomas, 2014)*
    - Displacement *(Gray et al, 2014)*
    - Inter-generational effects *(Cas et al, 2014)*

Large adverse consequences also for physical & environmental capital

- Tsunami destroyed bridges, roads, ports, buildings
- Agricultural fields made unproductive by saltwater intrusion
- Coral reefs, mangroves, coastal forests, wetlands, and estuaries severely negatively affected
- Groundwater reservoirs flushed with saltwater

Before: Banda Aceh

After: Banda Aceh

http://www.digitalglobe.com/

What about the consequences for economic output (GDP)?

Some of the channels through which Natural Disasters **NEGATIVELY** affect economic output

If person/firm engages in the same activity before and after the natural disaster:

- Productive capital (human, environmental, physical) which helped to generate output is damaged/destroyed. Examples:
  - Durable asset (machines etc.) destruction reduces productivity *(e.g. Anttila-Hughes & Hsiang, 2013)*
  - Physical capital destruction reduces productivity. E.g. a damaged road increases transportation costs
  - Human capital damages reduces productivity. E.g. a broken arm reduces the output per worker
  - Land degradation reduces productivity. E.g. agricultural fields flooded with saltwater make it hard to grow food *(see e.g. Hsiang 2010; or Deryugina, 2011)*

If person/firm engages in different activity:

  - Alternative activity less productive, otherwise the individual would have engaged in it already before the Tsunami

Using funds to replace destroyed capital means one cannot use them on something else instead *(Field et al, 2012)*

Some of the channels through which Natural Disasters **POSITIVELY** affect economic output

- Reconstruction boom & stimulus *(Skidmore & Toya, 2002; Hallegate, 2014)*
  - Replacing lost capital → Increases demand for goods and services *(Horwich 2000; Kunreuther 2007)*

- Capital destroyed was old & outdated
  - Disaster performs "service" of destroying old capital (to build a new and better infrastructure, old one would have had to be removed first, which has costs)
  - Productivity gains from upgrading capital higher than productivity losses from losing capital *(Hallegate and Dumas 2009; Cuaresma & Obersteiner 2008)*

- Stimulate innovation *(Skidmore & Toya 2002)*

- Marginal productivity of intact capital increases, as capital and labour become scarce after the destruction (inflow of wealth)

- Creates a more trusting and cohesive society *(Toya & Skidmore, 2014)*

- Causes outpouring of sympathy & increased trust *(Khalish, 2014)*

Empirical findings of natural disaster econ?

a.) Debate whether **moderate (or average)** natural disasters effect economic output positively or negatively:

- positive effects, bc of reconstruction *(Skidmore & Toya, 2002)*
  - **Only for moderate disasters *(Cuaresma & Obersteiner, 2008)***
- Depends on sector *(Loayza et al, 2009; Fomby et al, 2009)*
- Depends on development level, state of economic diversification etc *(Heger et al, 2009)*
- Meta study: overall, no recovery *(Cavallo & Noy, 2011)*

b.) **Extreme** natural disasters:

- Short-term growth & output
  - negatively affected *(Most studies. Examples using exogenous disaster variable: Strobl, 2011; Obersteiner & Groeschl, 2014)*

- Long-term growth & output
  - negatively affected *(see e.g. Hsiang & Jina, 2015)*
    - *A 90th percentile event reduces per capita GDP by 7.4% 20 years later.*
  - negatively affected /unaffected *(see e.g. Cavallo et al, 2013)*

If there is one case for creative destruction, i.e. increased GDP per capita, it is the case of Aceh

*"Aceh succeeded in **building back better.***"

Or something to this effect was mentioned by nearly every stakeholder, incl.:
– Bill Clinton (former special UN envoy to Tsunami recovery in Aceh)
– Aceh regional government
– BRR (Reconstruction and Rehabilitation agency)
– World Bank (Aceh Growth Diagnostic)
– UNDP (Beate Trankman, Indonesia country director)
– Scholars (e.g. Thomas Duncan)
– The Guardian, New York Times etc…

Aid quantity ↑. Largest reconstruction effort in the developing world
(World Bank, 2008 & Masyrafah & McKean, 2008)
– Aid ~ USD 7.5 bn (compared with USD 5 bn in damages).
– On average, countries receive about 10 percent worth of damages *(Freeman et al., 2002)*

Aid quality ↑. High quality administration and dissemination of aid.
– BRR => high efficiency and little corruption (of 7.5 USD bn, 7 USD bn made it to the destination)
– Sound fiduciary principles (Fengler et al, 2008)
– No aid fragmentation (Masyrafah & McKeon, 2008)
– No aid volatility (Masyrafah & McKeon, 2008)

Recovery: Banda Aceh

2004

2014

Source: Duke University

Source: gulfnews.com

The 2004 Indian Ocean Tsunami
A Natural Experiment

Thailand

Philippines

Vietnam   Laos

Aceh

Malaysia

N. Sumatra

Sumatra

Papua New Guinea

Australia

8 islands; 33 provinces; 426 districts

DATA

Link physical flooding measure to economic output

- Treatment: Indian Ocean Tsunami Flood maps
  - DLR (German Aerospace Center)
  - Dartmouth Flood Observatory
    - Fine-grained. Days after 24 Dec 2004.
  - RanD (Recovery Aceh Nias Database) data base
- Outcome measure: Economic Output
  - INDO-DAPOER (based on SUENAS)
    - Province Level GDP. 1983 – 2012.
    - District Level GDP. 1998 – 2012.
  - Night-Lights
    - NOAA
    - Grid-cell Level. 1992 – 2012.

Flood map creation

12

10

72
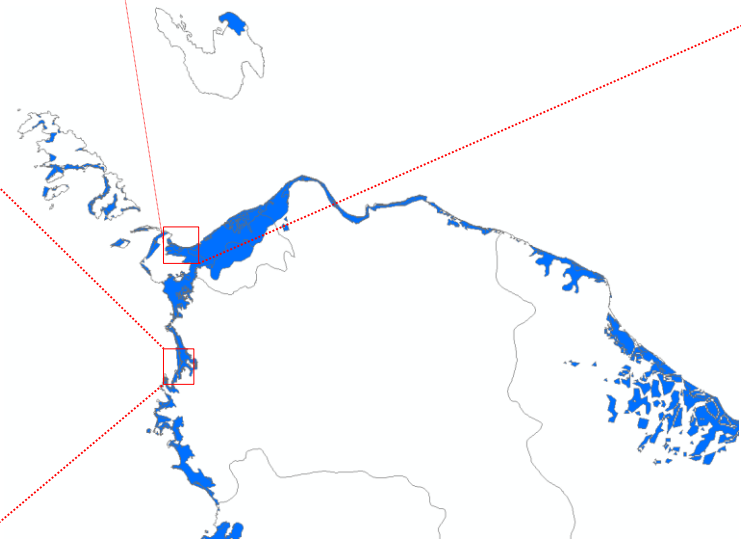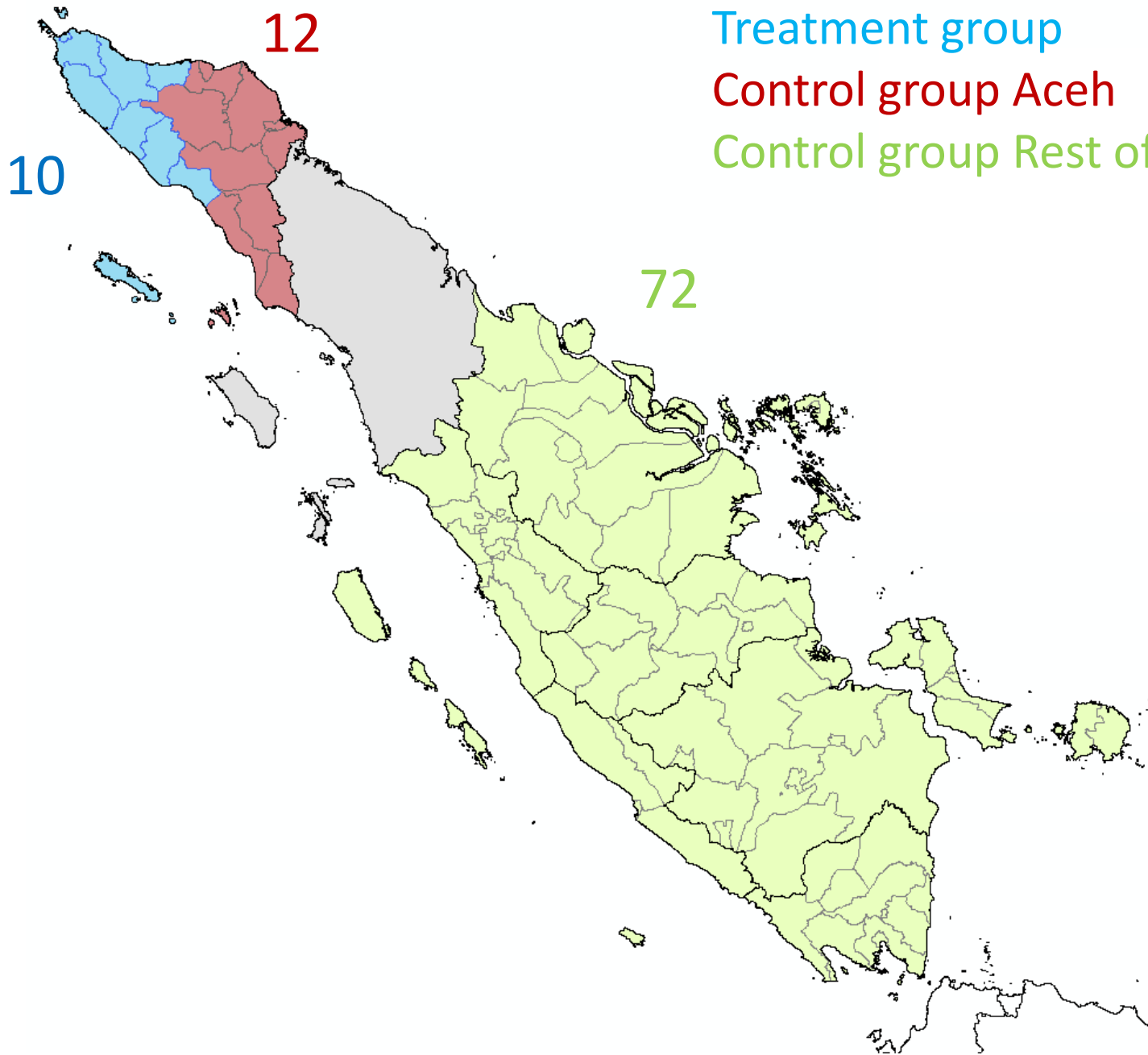
Treatment group
Control group Aceh
Control group Rest of Sumatra

12

29

72

Treatment group
Control group Aceh
Control group Rest of Sumatra
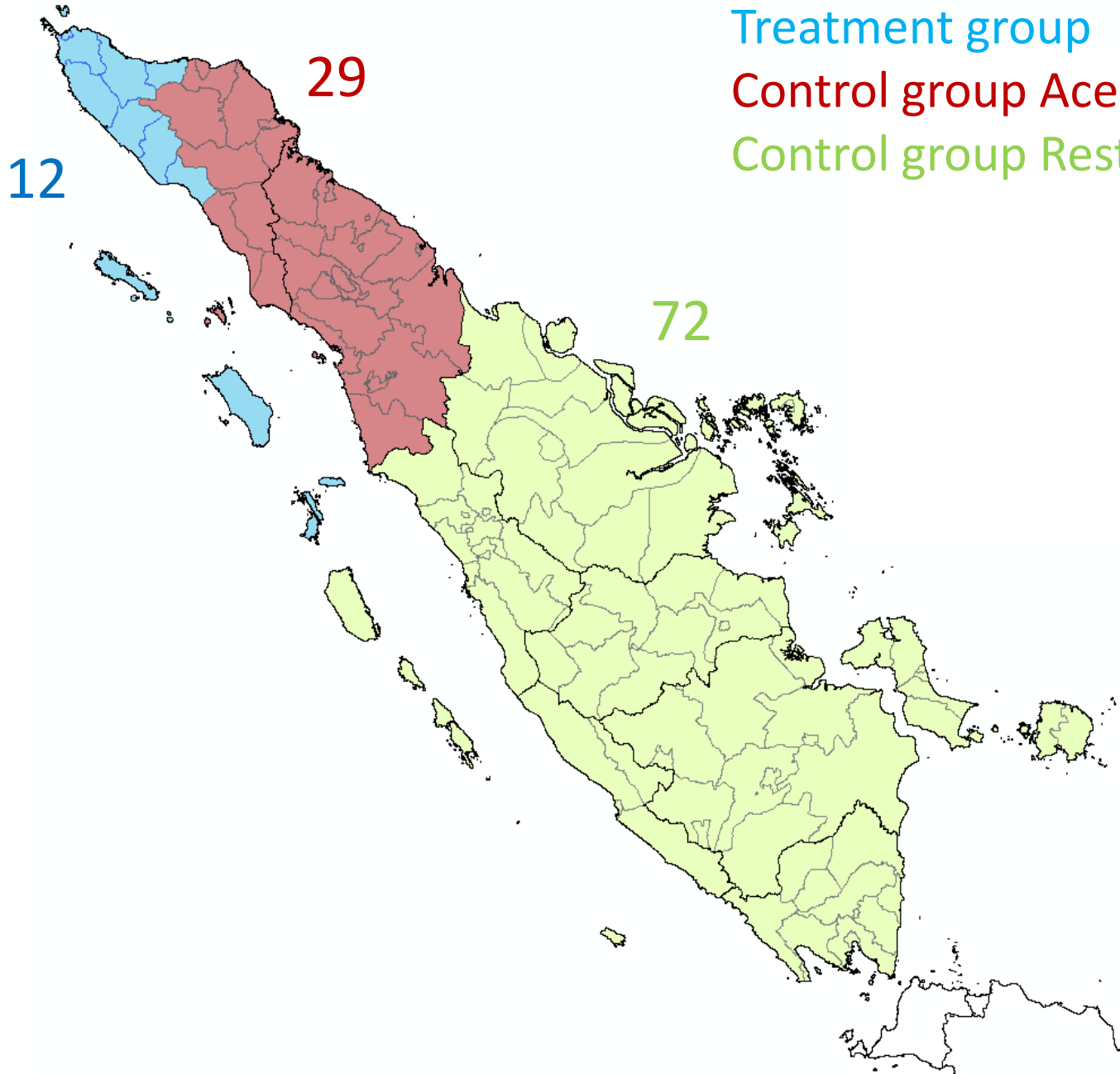
Conjoint treatment: Flood & Aid

- Quasi-experiment: power of experimenter limited
- Can only observe joint treatment **flooding & aid (and other assistance)**
- No pure aid treatment, or pure flooding treatment
- LATE – does not indicate how much of the effects are due to flooding & how much are due to aid
- Aid disbursed per person correlated with flooding intensity (share of flooded area, amount of people killed, and amount of people directly affected), coefficients ranging from 0.84 to 0.92

No automatism between aid & growth

Debate not settled in the literature:

Not back then:

- "Aid does not significantly increase investment and growth, … , but it does increase the size of government." (Boone, 1995).
- Burnside and Dollar (2000) → aid raises growth in a good policy environment.
- Easterly et al (2003) → aid hinders long term economic growth, because it stymies the private sector.
- Sachs "The End of Poverty" → big push for aid.
- Dani Rodrik (2008) shows that the overvalued exchange rate & inflation, as a results of such foreign inflows explains negative relationship between growth and inflows
- Cross-country growth regressions show a negative relationship between foreign aid/capital inflows and long-term growth (Rajan and Subramanian, 2011).

And not now:

Newer papers account for endogeneity bias, through IVs, regression discontinuity etc:

- Aid contributed to increased growth (Magesan, 2015; Galliani et al, 2014)
- Aid has no effect on growth (Dreher and Lohmann, 2015)

Discrepancy comes from different types of aid, sources of aid, aggregation strategies, different econometric methods and different lag structures (Berlin, 2015).

Estimation strategies: DiD

$$\ln(Y_{i,t}) - \ln(Y_{i,t-1}) = \alpha + \delta(D_i * T_t) + d_t + \gamma_i + \varepsilon_{it} \qquad (1)$$
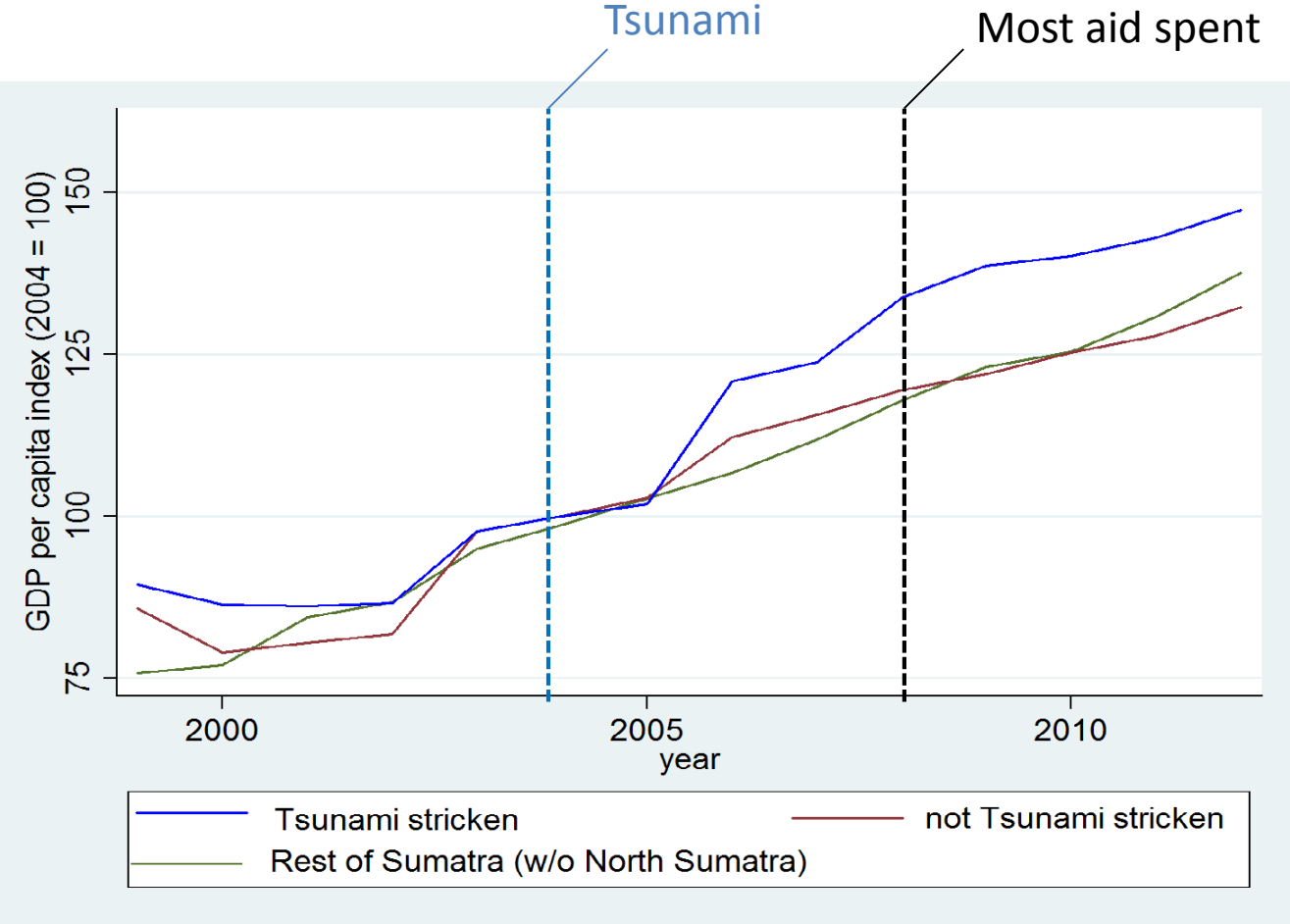
$$\ln(Y_{i,t}) - \ln(Y_{i,t-1}) = \alpha + \sum_{t=2005}^{2012} [\delta_t(D_i * T_t)] + d_t + \gamma_i + \varepsilon_{it} \qquad (2)$$

- Estimate with OLS
- Assume that ε
    - is heteroskedastic and serially corr a district for 10 years (Newey and West, 1987).
    - spatially corr across contemporaneous districts up to a distance of 100km (Conley 1999 & 2008). Decaying spatial kernel density weights a la Bartlett.

GDP mean comparison across groups
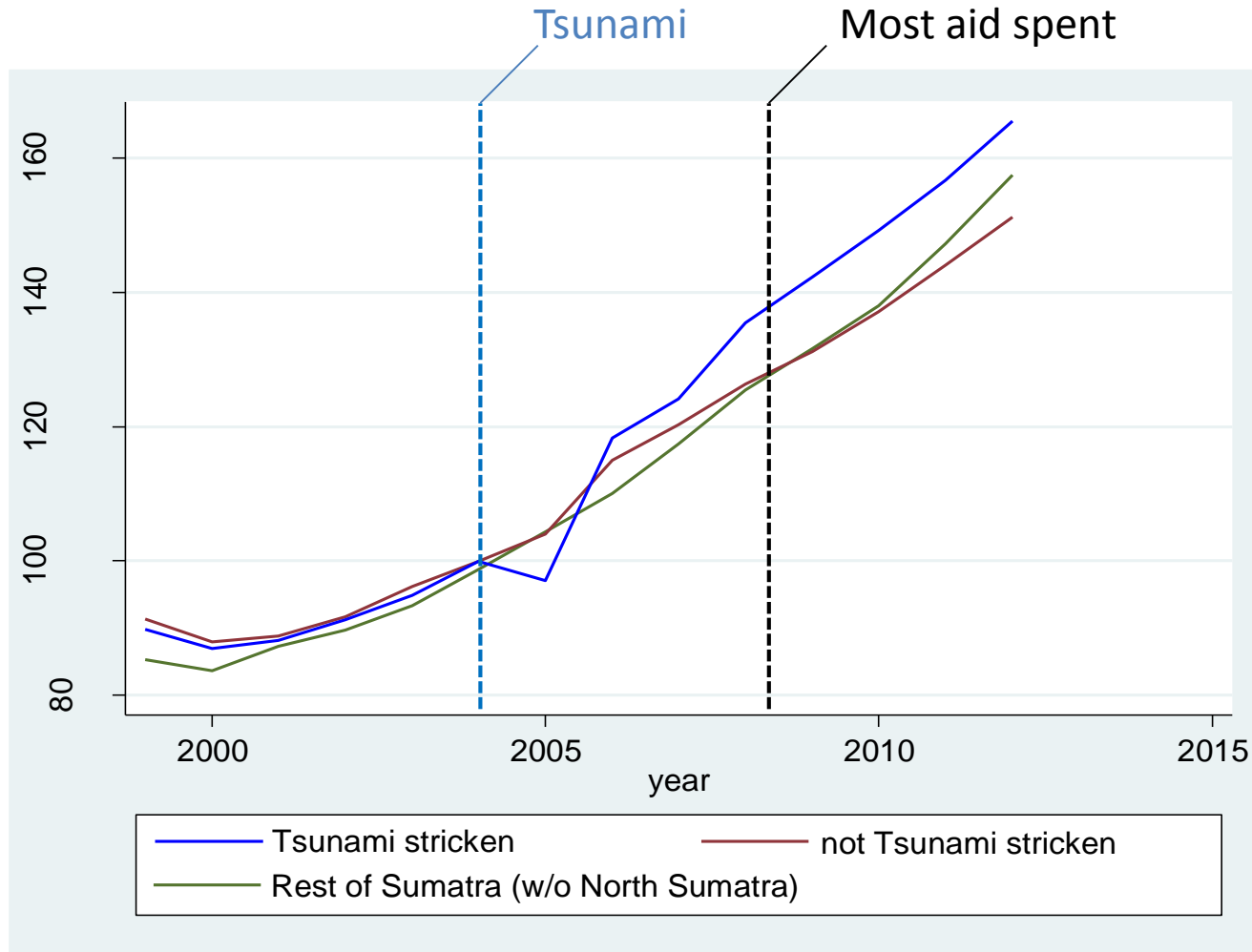
GDP per capita mean comparison

Tsunami-growth panel regressions, 1999 - 2012

	Tsunami affected districts (blue) in Aceh			
Treated group:				
Control group:	Sumatra control districts (red & green)		Non-Aceh districts (green)	Aceh non-flooded control districts (red)
Dependent Variable: GDP per capita growth rate				
Tsunami (average year)	0.041 *			
	(0.020)			
Tsunami_05		0.008	0.011	-0.004
		(0.030)	(0.030)	-(0.030)
Tsunami_06		0.154 ***	0.163 ***	0.101 ***
		(0.030)	(0.030)	(0.050)
Tsunami_07		0.012	0.014	0.005
		(0.020)	(0.020)	(0.010)
Tsunami_08		0.055 ***	0.056 **	0.048 ***
		(0.020)	(0.020)	(.)
Tsunami_09		0.023	0.024	0.02
		(0.020)	(0.020)	(.)
Tsunami_10		0.028 *	0.033 *	-0.003 *
		(0.010)	(0.020)	-(0.010)
Tsunami_11		0.014	0.016	0.008
		(0.020)	(0.020)	(.)
Tsunami_12		0.013	0.015	0.005
		(0.020)	(0.020)	(.)
Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
SE	Spatial HAC	Spatial HAC	Spatial HAC	Spatial HAC
Observations	1287	1287	1118	299
R-sqr	0.24	0.25	0.24	0.34

Impulse responses: Cumulative effect of the Tsunami on GDP per capita growth
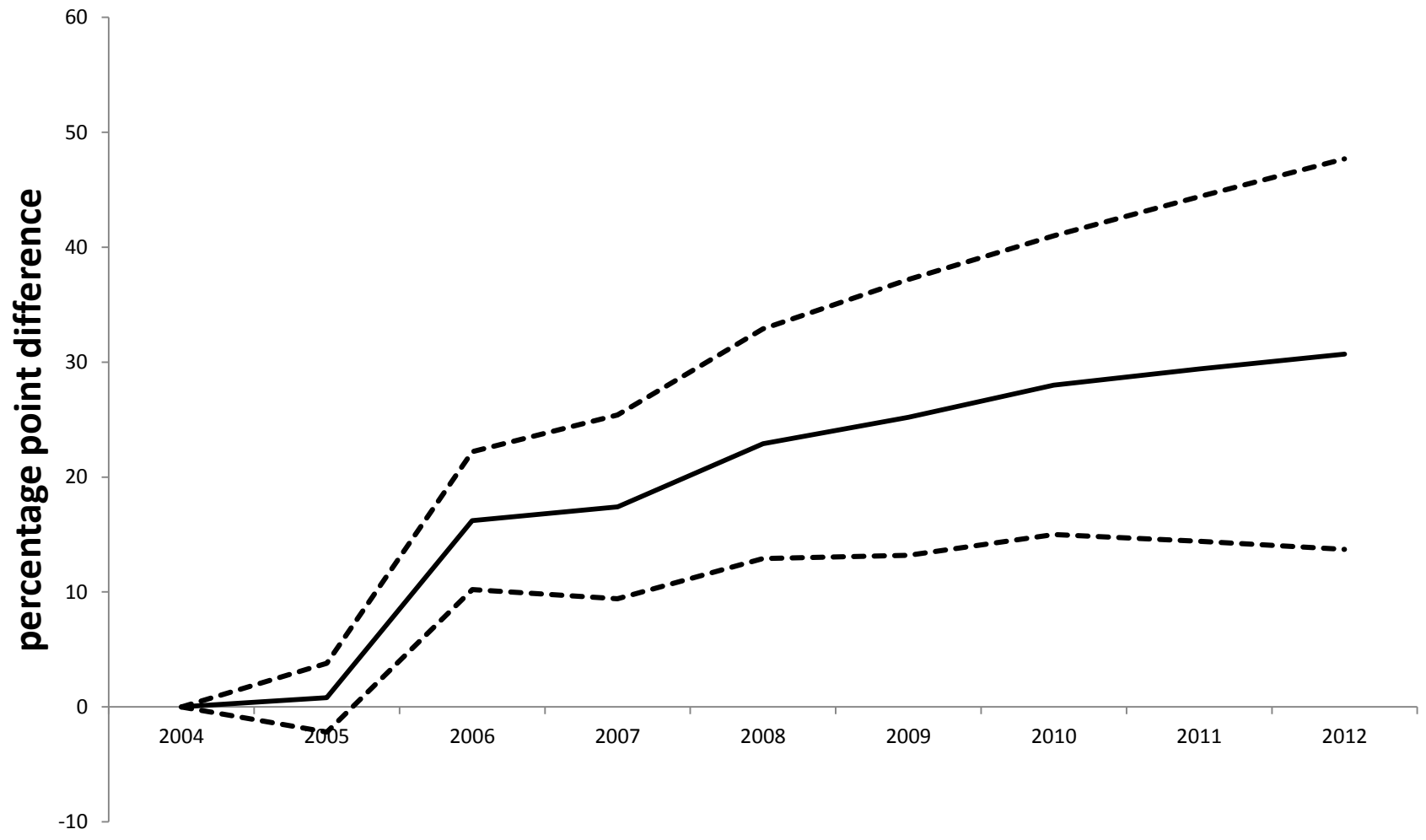
Robustness tests

I tried nearly everything to "shoot down" the creative destruction results, including:

1.   **Alternative sub-samples**
      - **Including North Sumatra**
      - **Excluding Banda Aceh**
      - **Excluding islands**
      - **Looking at coastal districts only**
      - **Looking at rural and urban districts separately**
2.   **Alternative specifications**
      - **District specific time trend**
      - **Group effects instead of district FEs**
      - **SE estimation (block BS, cluster, robust)**
      - **AR processes**
      - **Population weighted by district level**
3.   **Alternative units of analysis (sub-districts instead of districts)**
4.   **Alternative impact measures (night-lights instead of GDP)**
5.   **Alternative method (Synthetic Control and Comparative Case Studies)**
6.   **Placebo tests with synthetic control method**
      - **Random districts and variables**
7.   **Alternative treatment measure (different flood map; people killed per district)**

Tsunami intensity (the flooding "dose")

- Are there heterogeneous treatment effects depending on the intensity of flooding?
- As measures of flooding intensity, I use
  - Area flooded (% of sub-district area)
  - Population exposed to flooding (% of sub-district population)
- As output measures I use night-lights

Flooding intensity &
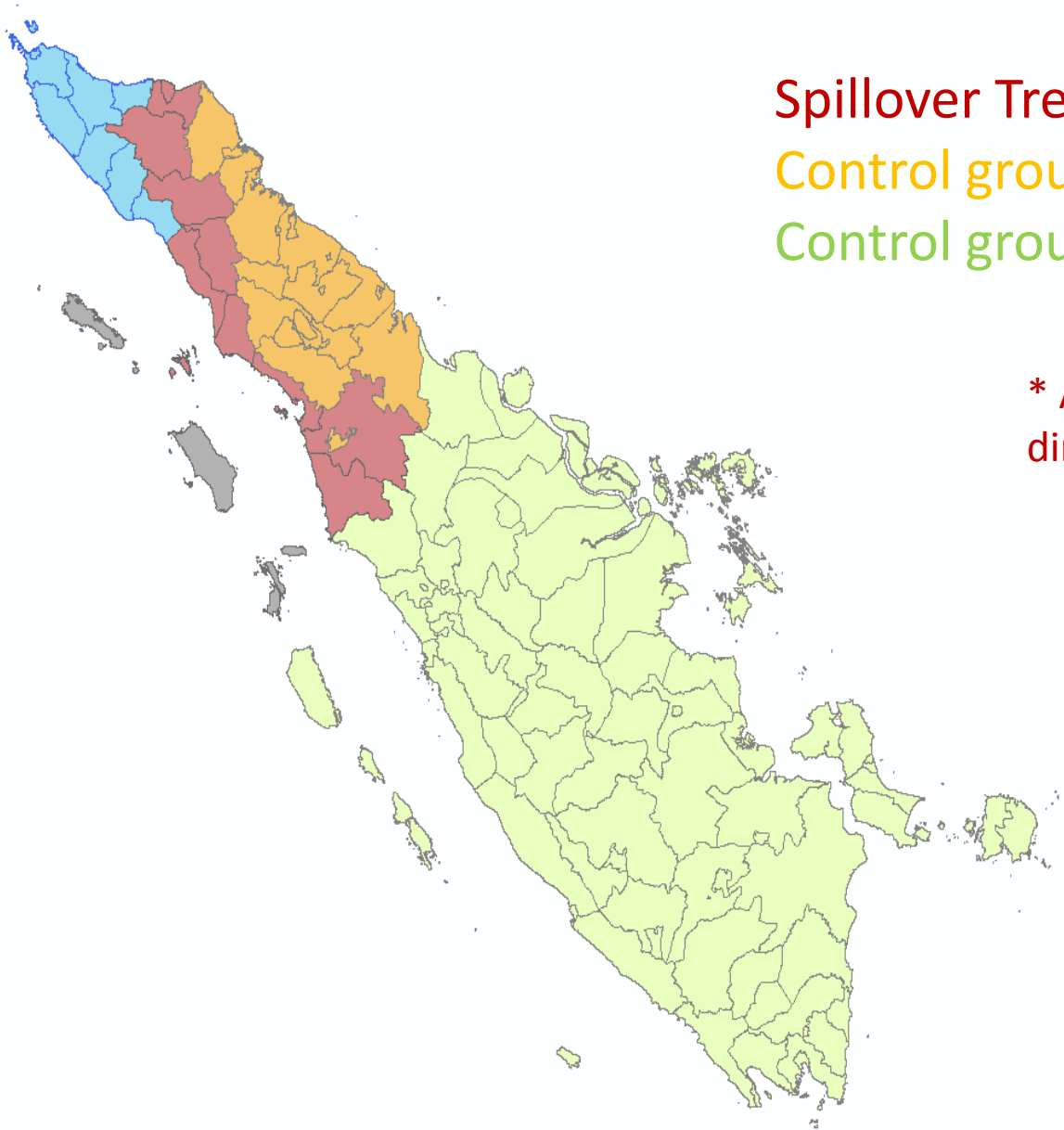light intensity measures
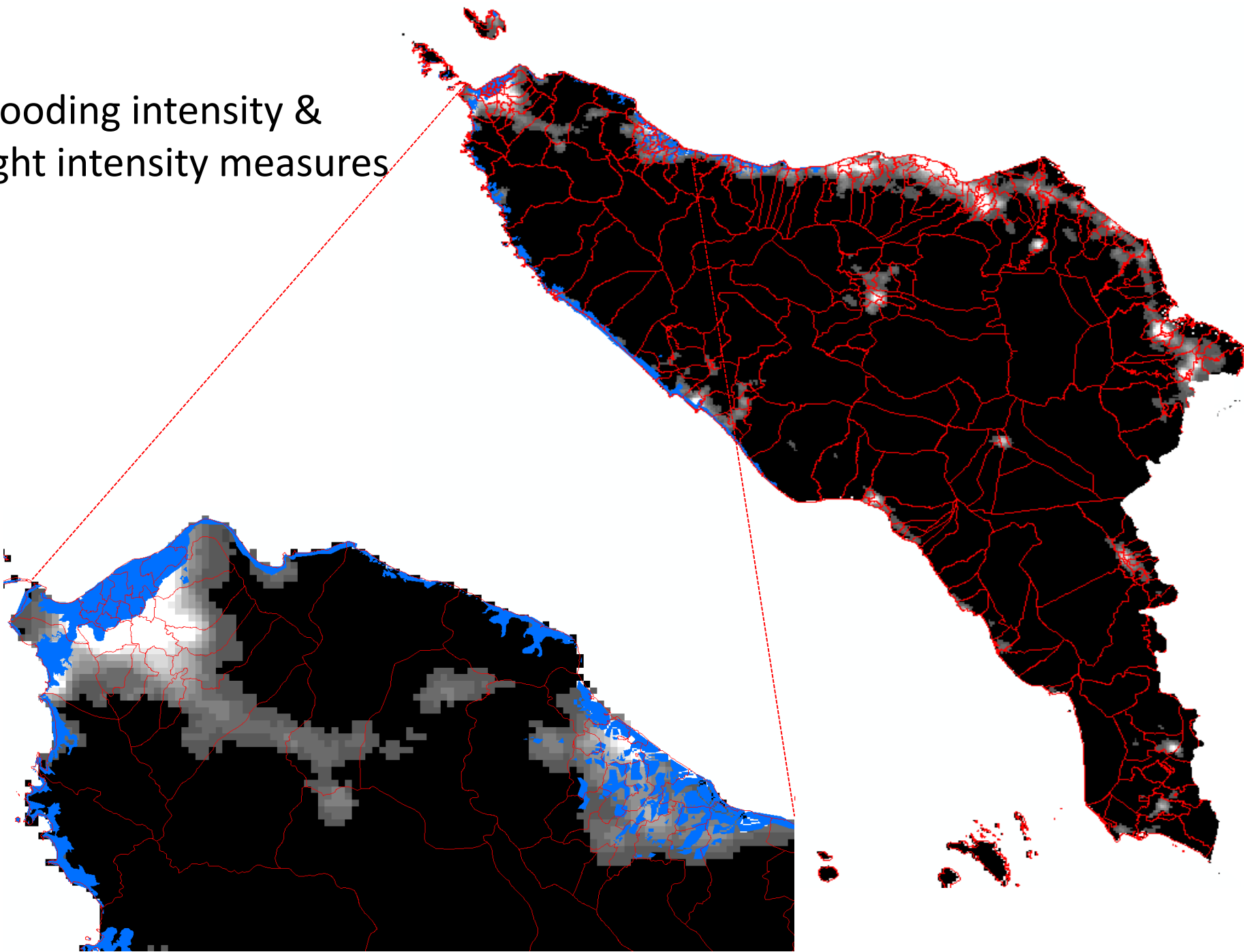
Night-light responses to flooding intensity (percentage of the Kecamatan's population affected)
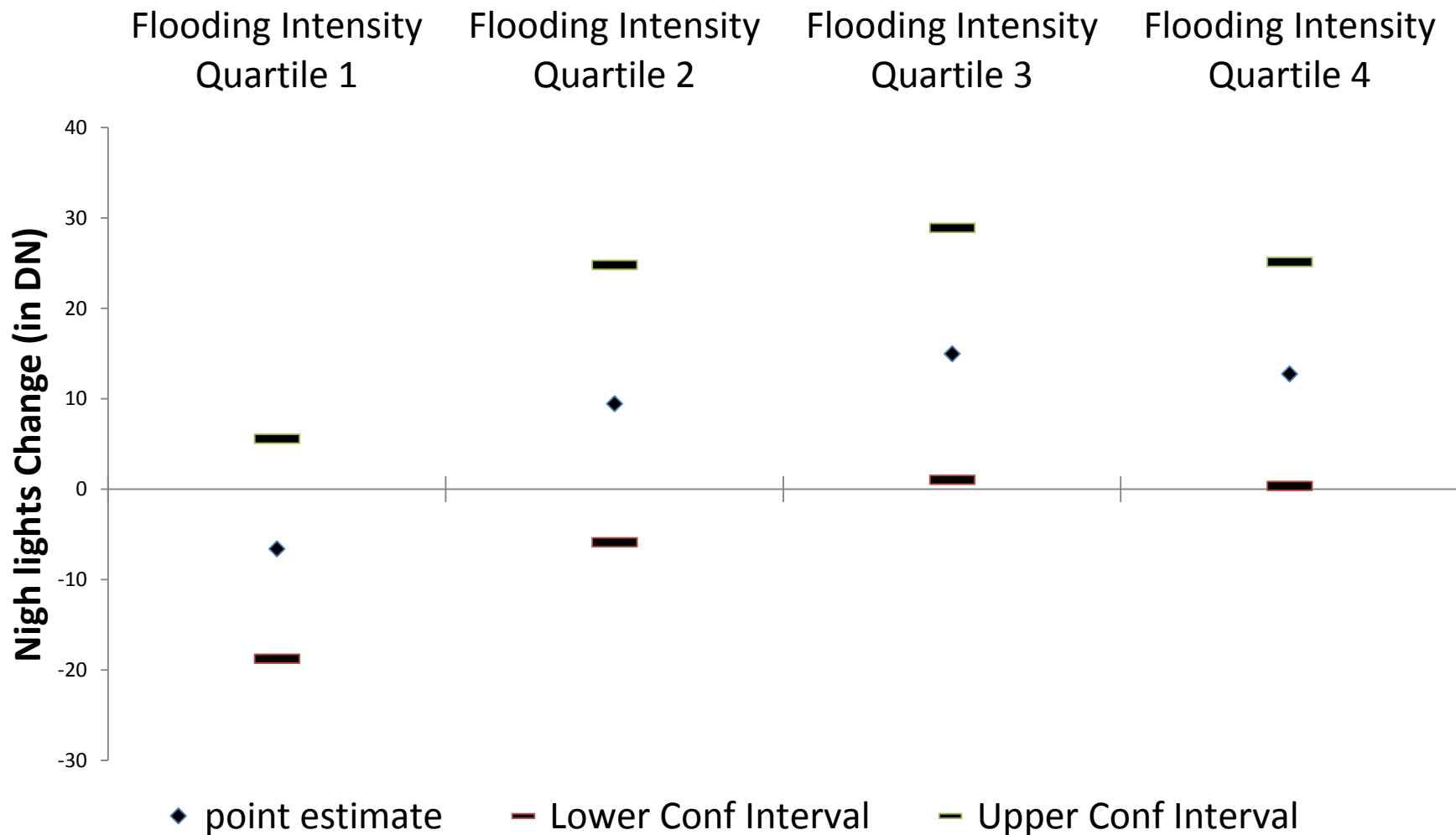
Night-light responses to flooding intensity (percentage of the Kecamatan's area flooded)
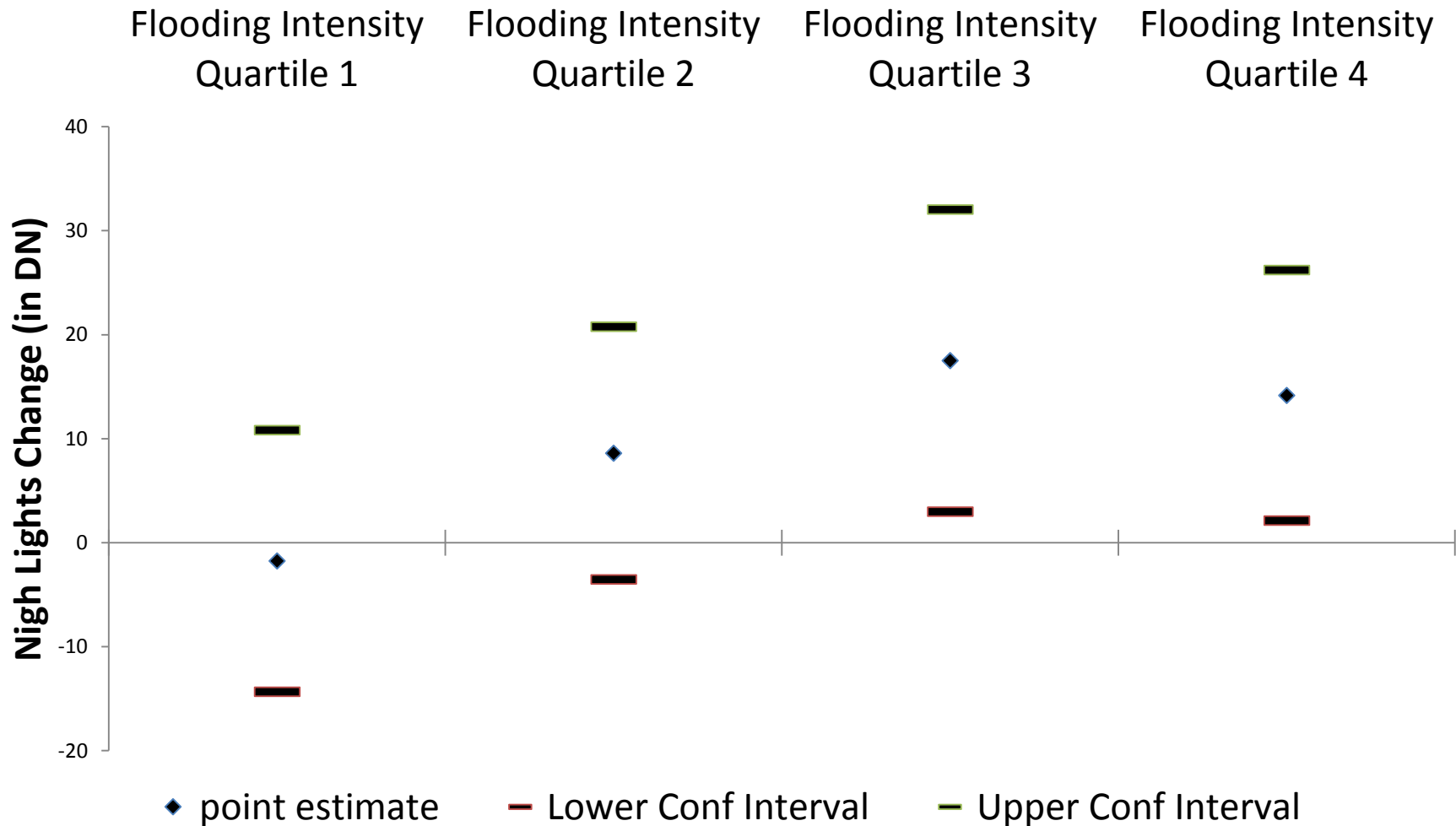
Creative destruction spillovers?

Spillover Treatment group*
Control group Aceh & North Sumatra
Control group Rest of Sumatra

* Ass.: Spillovers are more likely to direct neighbors of affected districts

It appears as if there are spillovers, but not statistically significant
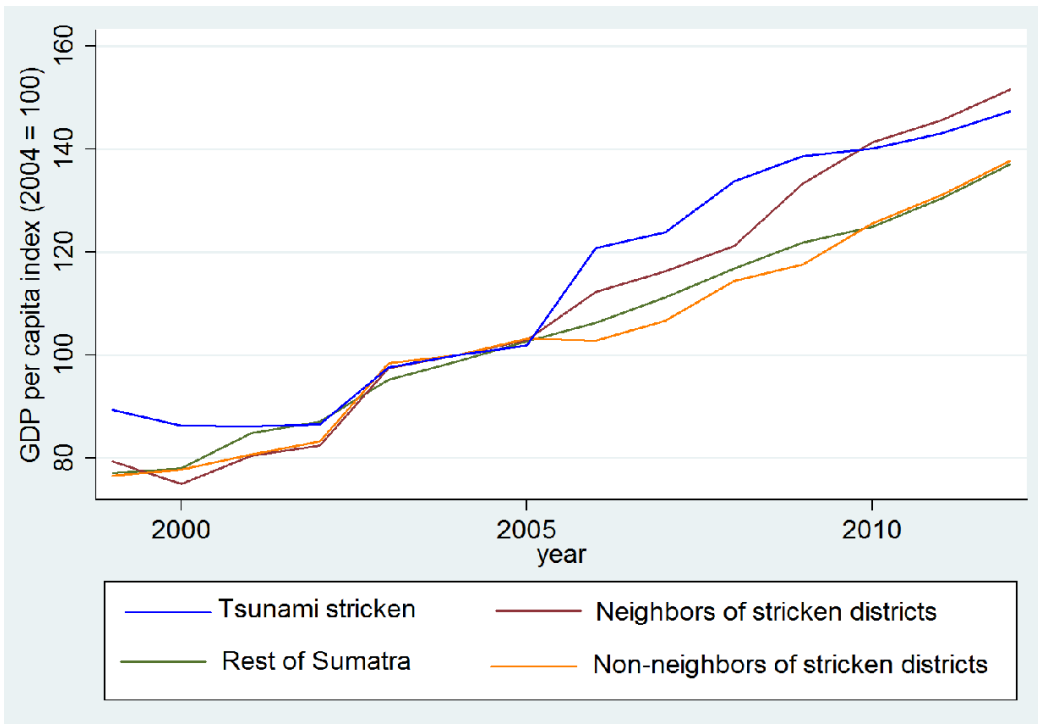
Treated group:	Direct neigbor districts (red) to flooded district	Direct neighbor districts (red) to flooded district
Control group:	Non-Aceh & non- N. Sumatra districts (green)	Non-neigbor districts (orange)
Dependent Variable: GDP per capita growth rate		
Tsunami_05	-0.014	0.001
	(0.016)	(0.020)
Tsunami_06	0.026	0.091
	(0.087)	(0.055)
Tsunami_07	-0.015	0.002
	(0.015)	(0.019)
Tsunami_08	-0.011	-0.045
	(0.015)	(0.068)
Tsunami_09	0.066	0.088
	(0.089)	(0.091)
Tsunami_10	0.033	0.001
	(0.021)	(0.026)
Tsunami_11	-0.016	-0.008
	(0.012)	(0.018)
Tsunami_12	-0.014	-0.004
	(0.017)	(0.020)
Year FE	Yes	Yes
District FE	Yes	Yes
SE	Spatial HAC	Spatial HAC
Observations	1235	364
R-sqr	0.24	0.26

How did the Tsunami (& aid) cause creative destruction?

3 channels investigated:

1. Investment bonanza
2. Private Consumption was not only smoothed, but boosted
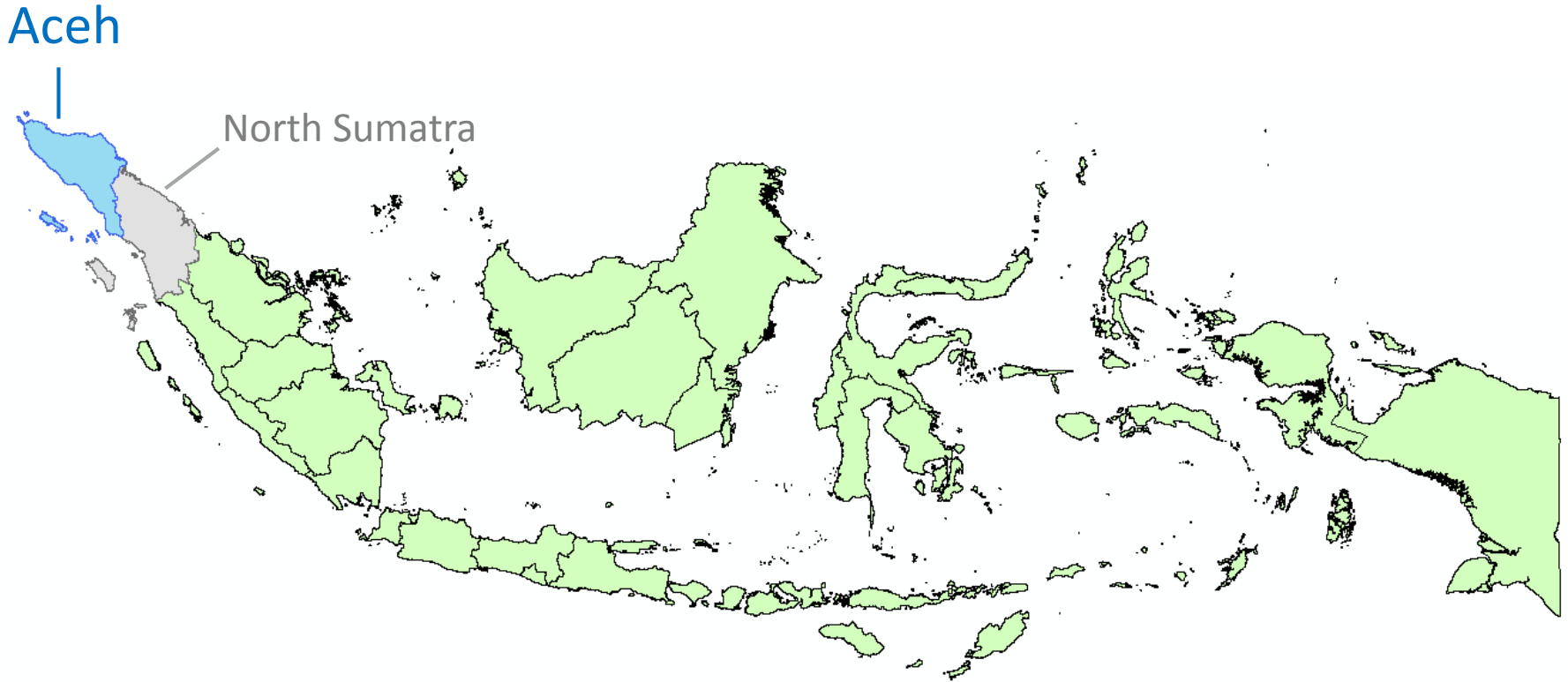3. Acceleration of Structural Transformation

1. Investment bonanza

– **building back more** and **building back better**
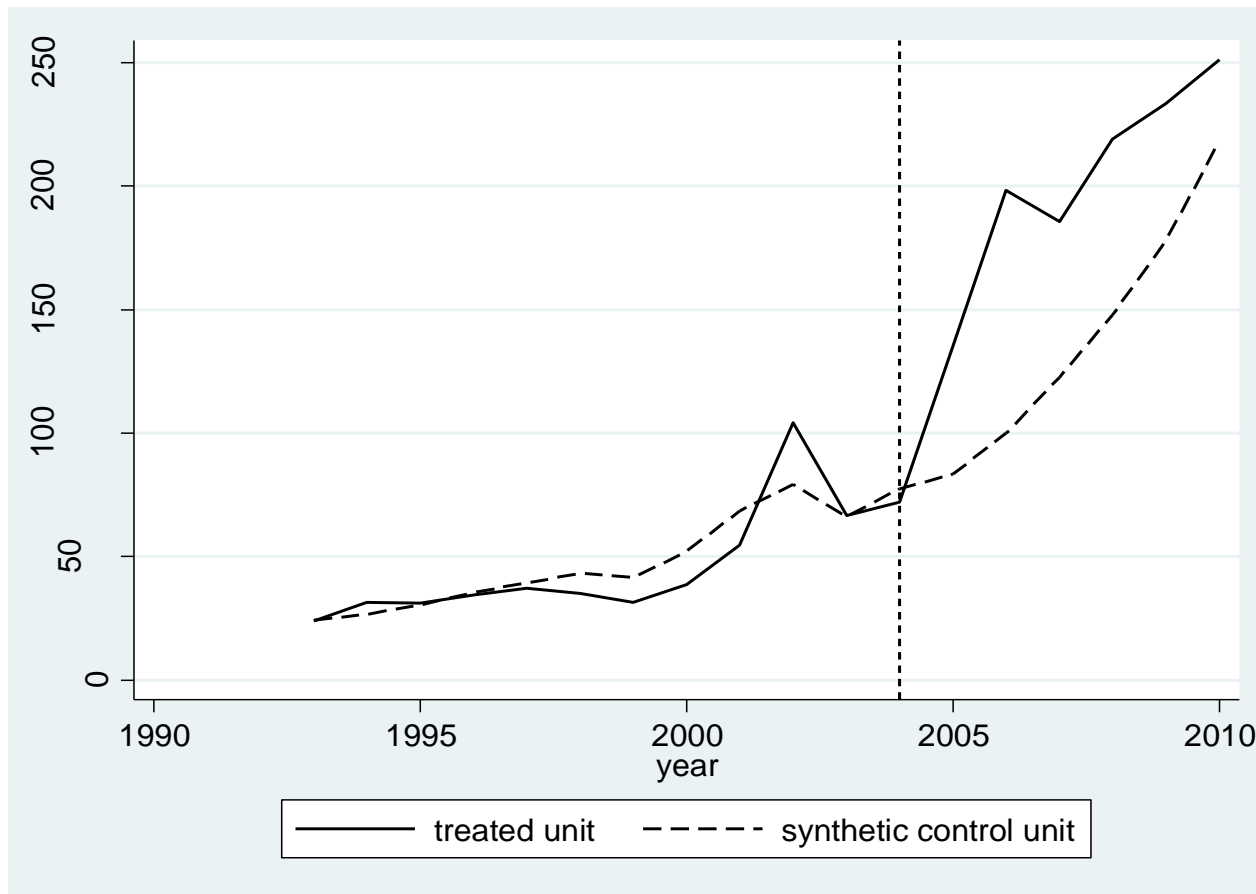
More Schools, hospitals and roads after the Tsunami:
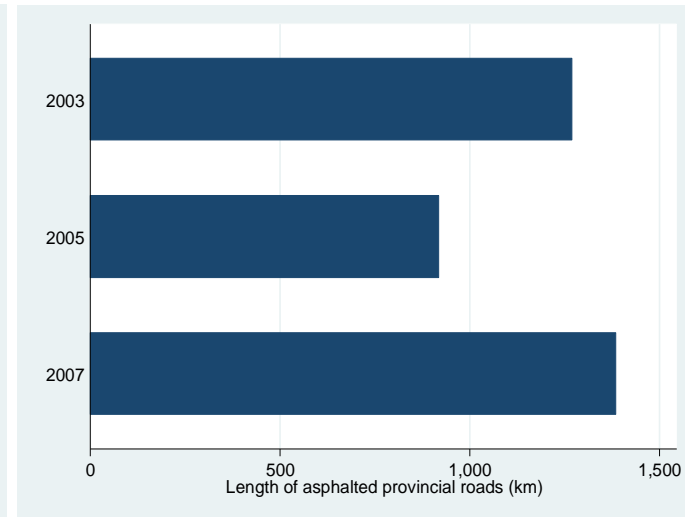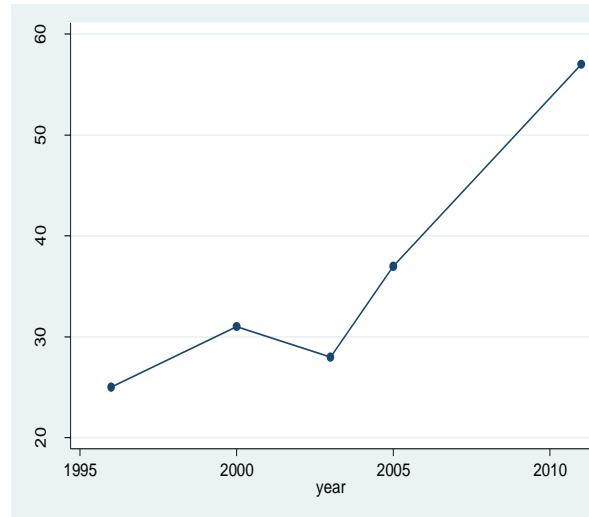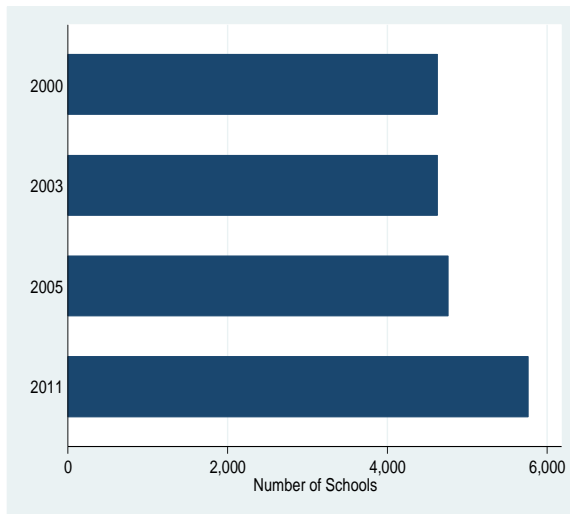
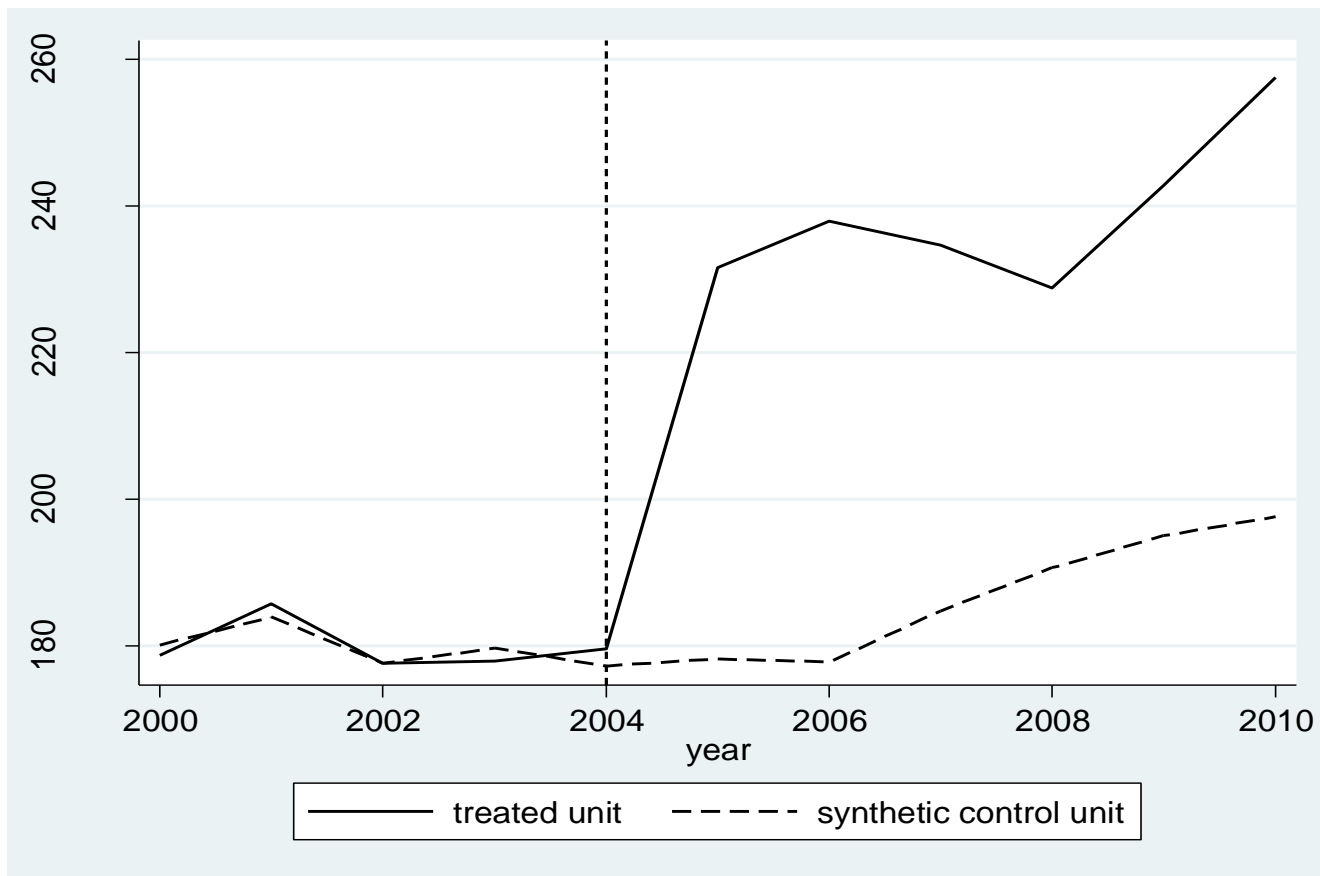# 1(or 2) "Tsunami treated" province(s), 31(or 32) untreated

Aceh

North Sumatra

1. Investment bonanza (cont'd)

Aceh versus synthetic Aceh: Capital formation per capita rates

2. Private Consumption Boosted

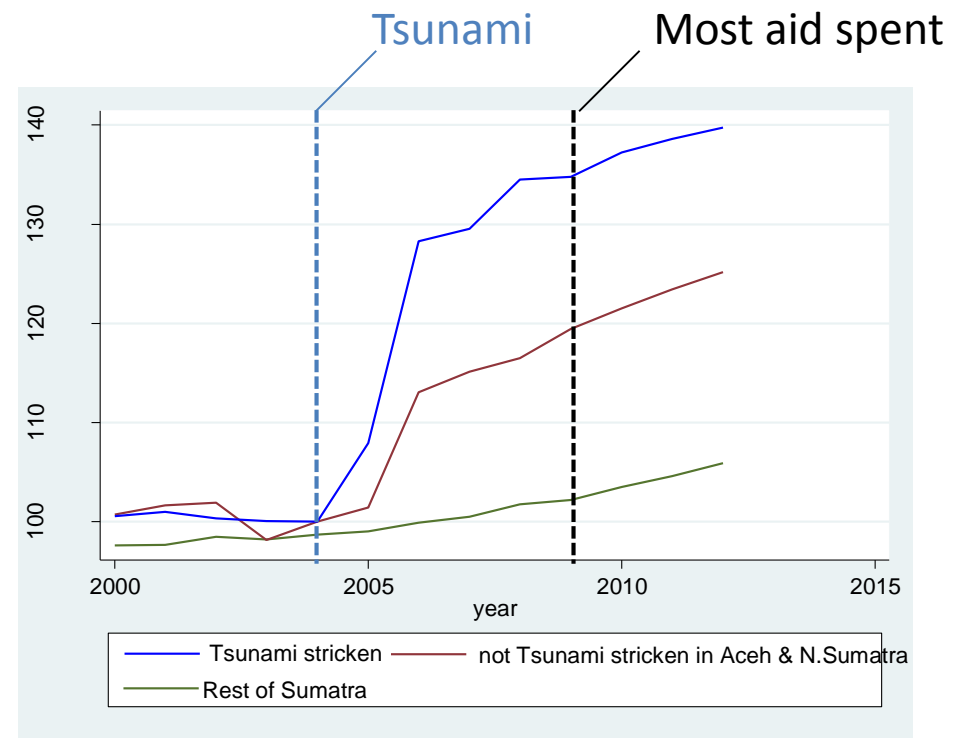Aceh versus synthetic Aceh: Private consumption per capita

3. Structural transformation

Tsunami accelerated structural transformation:
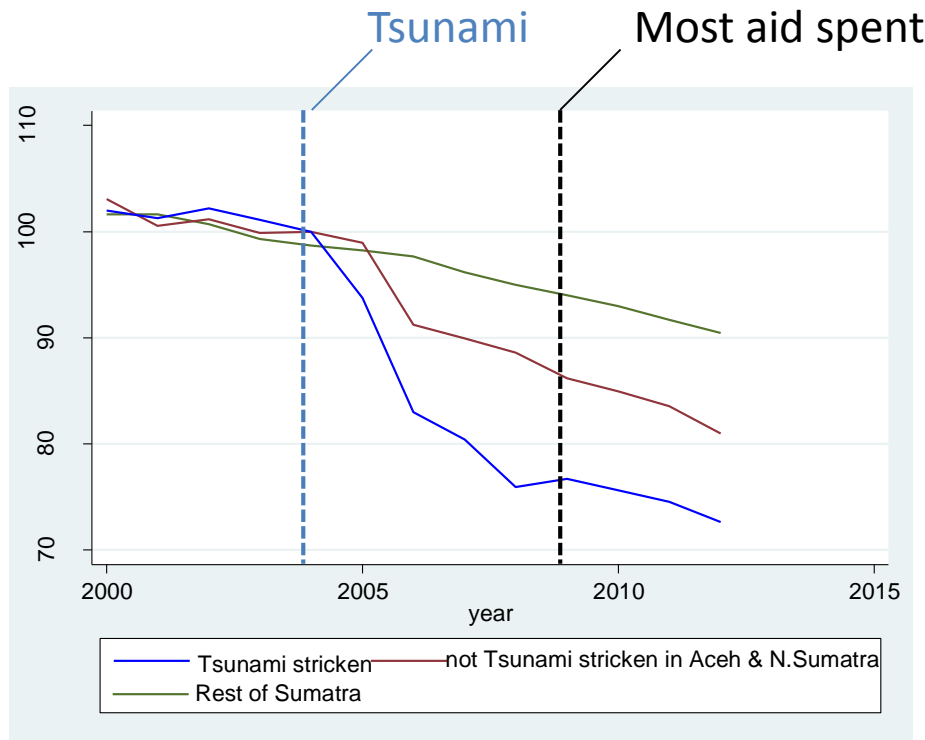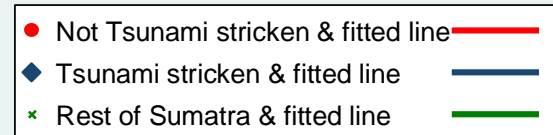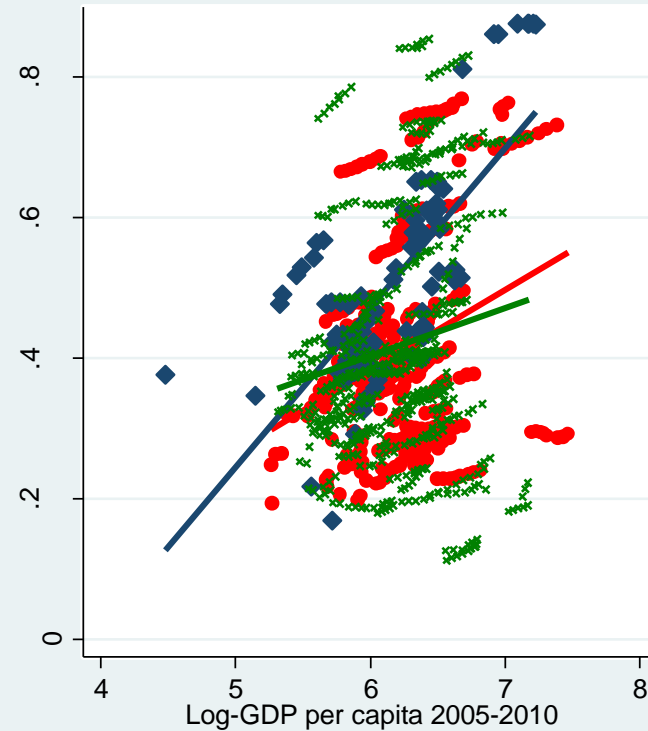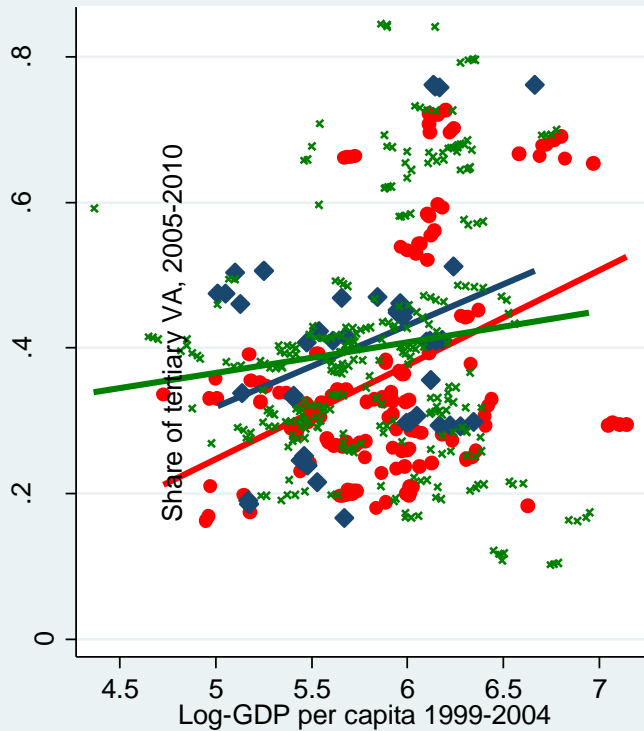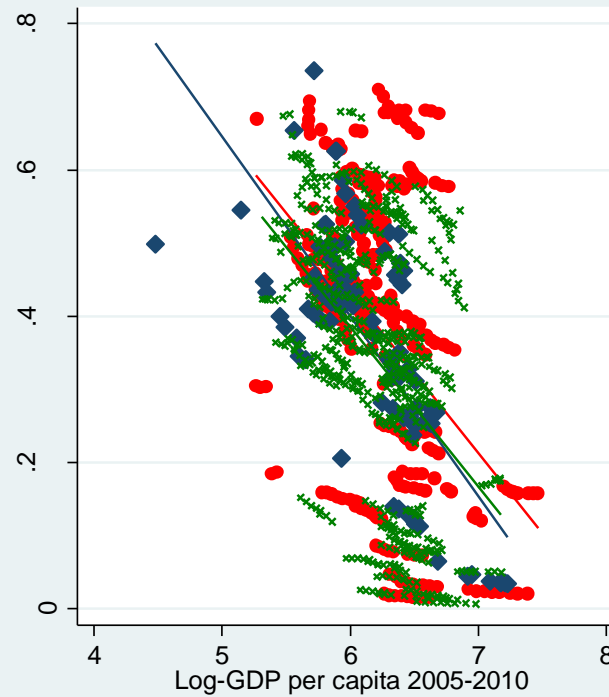
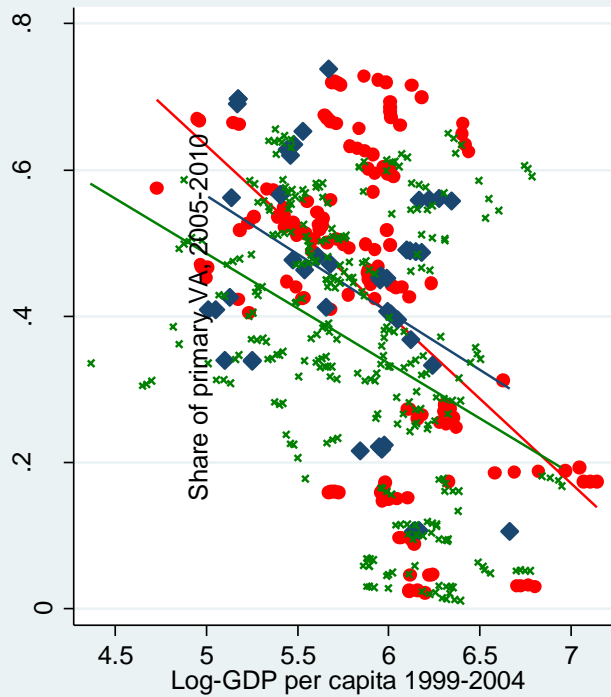Primary sector: Tertiary sector:

Tertiary sector growth has accelerated due to the Tsunami

Tertiary sector VA - Before and after the Tsumami

Primary sector drop has accelerated due to the Tsunami

Primary sector VA - Before and after the Tsumami

Top 4 Conclusions

1. Extreme natural disasters need not be persistently depressing for the economy. It's a political (human) choice if they are. If paired with aid and recovery assistance like in Aceh, they can be a "window of opportunity."

2. Disaster aid worked (but comes with challenges)

3. Tsunami and aid lastingly transformed the economy:
   - For the better: capital was built back better; higher rates of investment; boosted consumption & structural transformation
   - For the worse: reduced exports; crowded out of private sector (public sector increased significantly) & increased unemployment

4. Going beyond national averages is crucial. Nation-level analysis too coarse and aggregates countervailing trends.

Future research directions

1. What exactly caused creative destruction?
   - Disentangle joint treatment: flooding intensity & aid intensity
     - Investigate the single unconditional effects
2. Which aid programs were most successful?
3. Nonlinear flooding & aid effects. Would the creative destruction effect also have been achieved with less aid?
4. Marginal aid efficiency metrics. How large is the additional growth per additional unit of aid spent?
5. General equilibrium effects. USD 7 billion spent on recovery. What would have been the economic benefits had aid been spent on activity X in location Y instead.
6. How much increased output during the recovery phase is obtained from replacing the destroyed capital versus from using the replaced better capital more productively.
7. Why exactly did structural transformation occur?