

SOLVE THE RIDDLE ON INFRASTRUCTURE-DEBT NEXUS FROM OUTER SPACE

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ADVANTAGES OF USING THE NIGHTTIME LIGHTS TO MEASURE ECONOMIC GROWTH:

- An unbiased source;
- Flexible with the geographic scope.

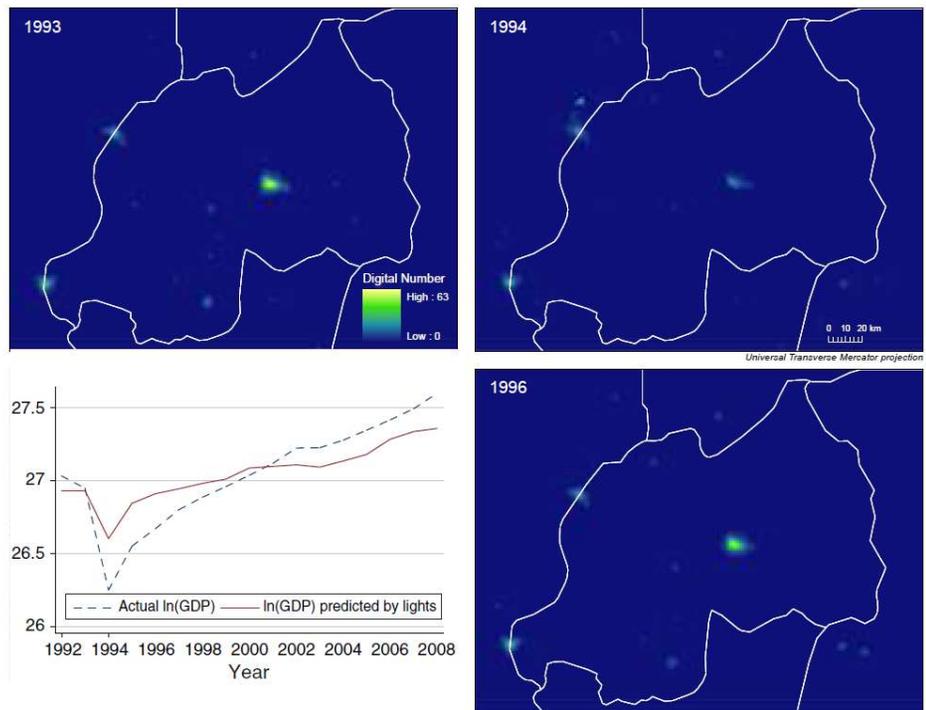
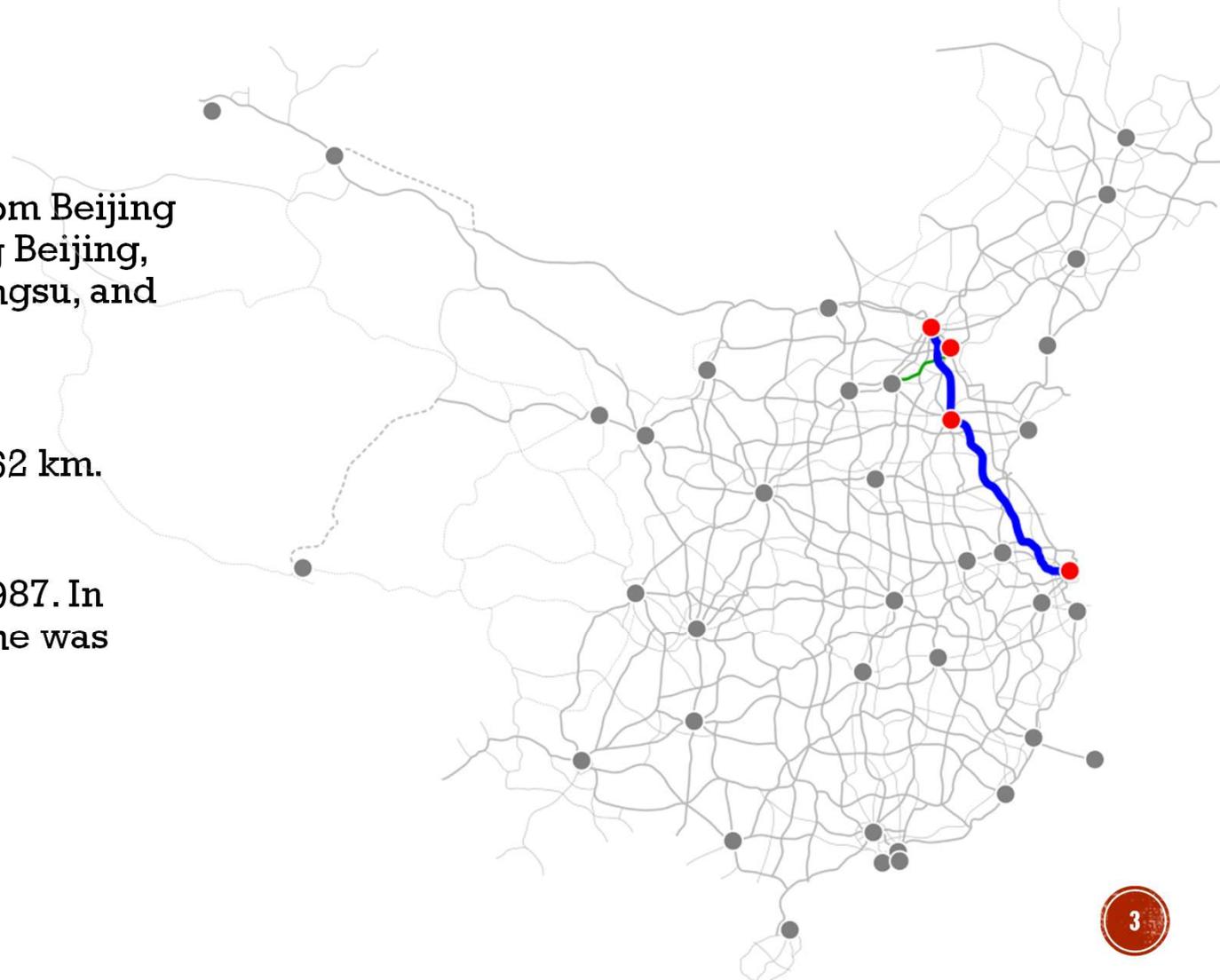


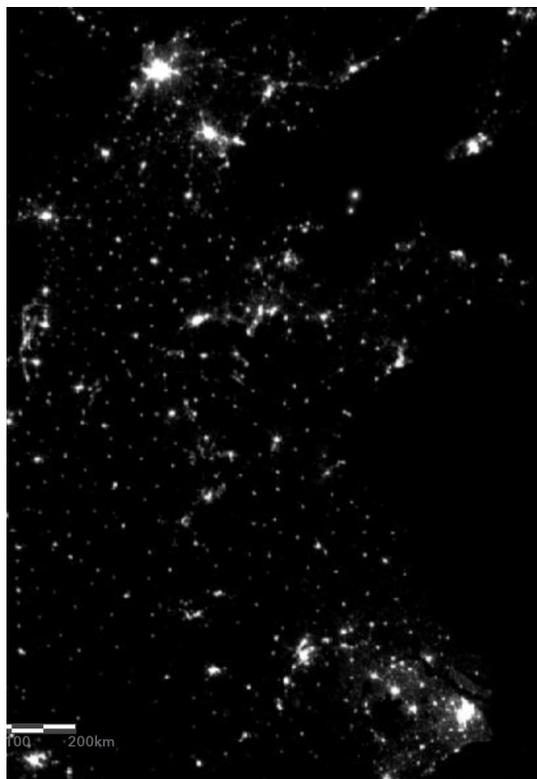
FIGURE 4. GENOCIDE EVENT: RWANDA

• Source: Henderson, Storeygard, and Weil (AER, 2012)

- **Jinghu Expressway** starts from Beijing and ends in Shanghai, linking Beijing, Tianjin, Hebei, Shandong, Jiangsu, and Shanghai.
- The total length is around 1262 km.
- The construction started in 1987. In November 2000, the whole line was completed.



1992 VS. 2000



http://www.arcgis.com/home/webmap/viewer.html?url=https%3A%2F%2Fgis.ngdc.noaa.gov%2Farcgis%2Frest%2Fservices%2Fdmisp%2Favg_lights_x_pct%2FImageServer&source=sd

QUESTIONS:

- (1) Whether are the nighttime lights getting brighter;
- (2) How long does it take for the nighttime lights to become brighter;
- (3) What are the rankings of economies in terms of the effectiveness of the infrastructure investments;
- (4) What are the relationships between debt and effectiveness?

LITERATURES REVIEW

- Henderson, Storeygard, and Weil (AER, 2012) use aggregate brightness during nighttime, as seen from outer space, as an indicator of economic activity.
- Pinkovskiy and Sala-i-Martin (QJE, 2016) use nighttime light as an instrument to realign the economic development based on the national account and based on household surveys.
- Strong correlations between nighttime light and electricity consumption were also found by Proville, Zavala-Araiza, and Wagner (PLOS ONE, 2017).
- AidData (2018) matched the nighttime lights with the location of China-financed infrastructure in developing countries to assess the latter's impact on economic growth and inequality.
- The intensity of light in nighttime satellite images is used as a proxy for power infrastructures by Ghai, Ismail, and Pakala (Stony Brook University, 2018).

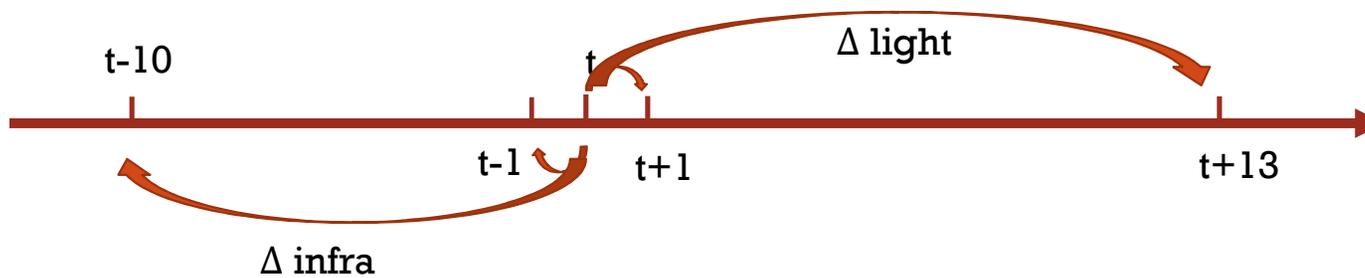
DATA

- **Nighttime lights data:** Version 4 DMSP-OLS Nighttime Lights Time Series from **1992 to 2013** provided by the US National Oceanic and Atmospheric Administration (NOAA) at <http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html>;

- **Infrastructure Data:**
- Calderón, C., E. Moral-Benito and L. Servén (2014) "Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach", Journal of Applied Econometrics:
 - **Paved roads:** total length of paved roads in kilometers per thousand workers;
 - **Electricity:** electricity generating capacity in gigawatts per thousand workers;
 - **Rails:** total length of rail in kilometers per thousand workers.

METHODOLOGY

- Rolling window approach:
 - Based on the data availability, we choose the lags of infrastructures such as paved roads as $l = 1, 2, \dots, 10$ and the heads of nighttime light as $h = 1, 2, \dots, 13$.



CORRELATIONS BETWEEN THE INFRASTRUCTURE INVESTMENTS AND THE BRIGHTNESS OF LIGHTS

- Calculate correlations between the changes in infrastructures from $t - l$ to t and the changes in brightness of lights from t to $t + h$ with $t \in [1992, 2000]$ for each combination of l and h .

- Selection criteria:
 - 1. The correlations are positive;
 - 2. The correlation estimates are significant at least at 10%.

ON PAVED ROADS ...

Table 1. Number of countries with significant positive correlations between changes in the paved road and changes in brightness of lights with $N \in [90, 95]$

Heads of Light Brightness h	1	2	3	4	5	6	7	8	9	10	11	12	13
1	3	8	5	4	13	9	5	4	7	3	9	9	6
2	3	10	8	9	11	12	12	10	11	5	8	9	7
3	2	5	11	11	20	13	17	14	14	3	7	10	7
4	0	5	4	12	17	12	12	12	9	2	6	7	6
5	1	3	3	12	13	14	11	7	6	2	5	9	6
6	1	4	6	10	14	13	6	8	7	5	5	9	6
7	0	7	6	9	14	11	8	8	7	3	5	5	4
8	0	5	6	11	15	9	10	9	11	2	3	7	5
9	0	3	5	10	12	11	8	7	6	2	2	6	4
10	1	1	4	8	9	10	8	6	8	2	3	6	7

ON ELECTRICITY...

Table 2. Number of countries with significant positive correlations between changes in electricity generated and changes in brightness of lights with $N \in [90, 95]$

Heads of Light Brightness h	1	2	3	4	5	6	7	8	9	10	11	12	13
1	5	4	0	3	6	7	5	3	4	3	4	8	0
2	3	6	5	8	5	11	6	6	8	6	7	9	7
3	2	8	7	5	4	8	7	6	7	6	9	9	8
4	3	7	5	4	5	8	5	8	8	4	8	7	4
5	1	4	2	2	4	8	9	7	6	8	10	8	7
6	1	3	2	4	5	15	7	11	9	7	9	9	7
7	1	5	4	5	9	14	12	10	10	11	7	9	3
8	1	5	6	4	6	11	14	13	11	9	6	7	4
9	2	3	6	3	4	13	14	14	9	7	5	6	6
10	3	5	4	2	7	12	13	11	11	8	3	7	1

ON RAILS ...

Table 3. Number of countries with significant positive correlations between changes in rails and changes in brightness of lights with $N \in [90, 95]$

Heads of Light Brightness h	1	2	3	4	5	6	7	8	9	10	11	12	13
1	5	2	1	1	4	3	3	2	1	2	2	1	1
2	2	4	4	4	5	4	2	5	5	4	2	5	7
3	1	6	4	8	7	9	5	8	7	4	4	7	5
4	1	4	0	9	7	8	6	8	6	6	7	8	6
5	1	4	3	4	4	11	10	7	9	7	5	9	6
6	2	2	0	7	5	11	9	7	5	6	4	5	5
7	1	2	0	6	3	11	7	3	5	4	5	6	5
8	0	4	3	6	5	12	7	3	7	6	6	5	8
9	2	2	2	7	8	12	7	4	5	9	7	5	6
10	0	2	2	7	9	11	9	6	11	4	7	4	3

OBSERVATIONS

- The frequency of significance: paved roads (953), electricity generated (842), and rails (661).
- Different combinations of $[l, h]$ to have the most number of countries with significant correlations:
 - $[3, 5]$ for paved roads (with a number of obs. as 20);
 - $[6, 6]$ for electricity generated (with a number of obs. as 15);
 - $[8/9, 6]$ for rails (with a number of obs. as 12).

**MEASURE THE EFFECTIVENESS OF INFRA INVESTMENT
USING DIFFERENCES BETWEEN THE CHANGES IN LIGHT
BRIGHTNESS AND THE CHANGES IN INFRASTRUCTURE
INVESTMENT**

MEASURE THE EFFECTIVENESS OF INFRA INVESTMENT USING THE DIFFERENCE BETWEEN THE CHANGES IN BRIGHTNESS AND THE CHANGES IN INFRASTRUCTURE INVESTMENT

$$\blacksquare R_{i,t}^{lh} = \left(\frac{Light_{i,t+h}}{Light_{i,t}} - 1 \right) / h - \left(\frac{Infra_{i,t}}{Infra_{i,t-l}} - 1 \right) / l,$$

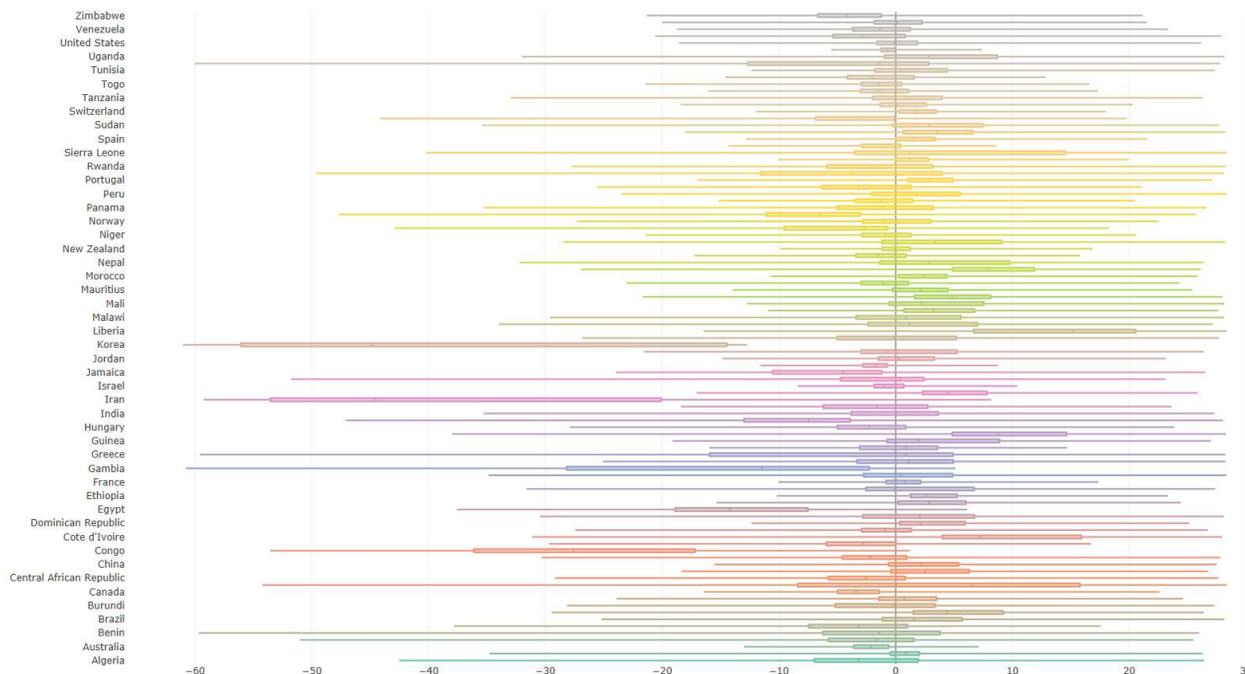
where $t \in [1992, 2000]$, the lags of infrastructure investment $l = 1, 2, \dots, 10$, and the heads of nighttime light $h = 1, 2, \dots, 13$.

- $R_{i,t}^{lh}$ is the difference between the annualized growth rate of light brightness and the annualized growth rate of infrastructure investment.
- Higher $R_{i,t}^{lh}$ indicates that the infrastructure investment is more effective in terms of bringing higher economic growth (measured by lights).

GROWTH RATE DIFFERENCE BETWEEN LIGHT AND PAVED ROADS (ANNUALIZED %)

- Countries with a high value of median $R_{i,t}^{lh}$ (%):

Liberia (15.19),
 Honduras (8.79),
 Mozambique (7.96),
 and Cote d'Ivoire (7.25).

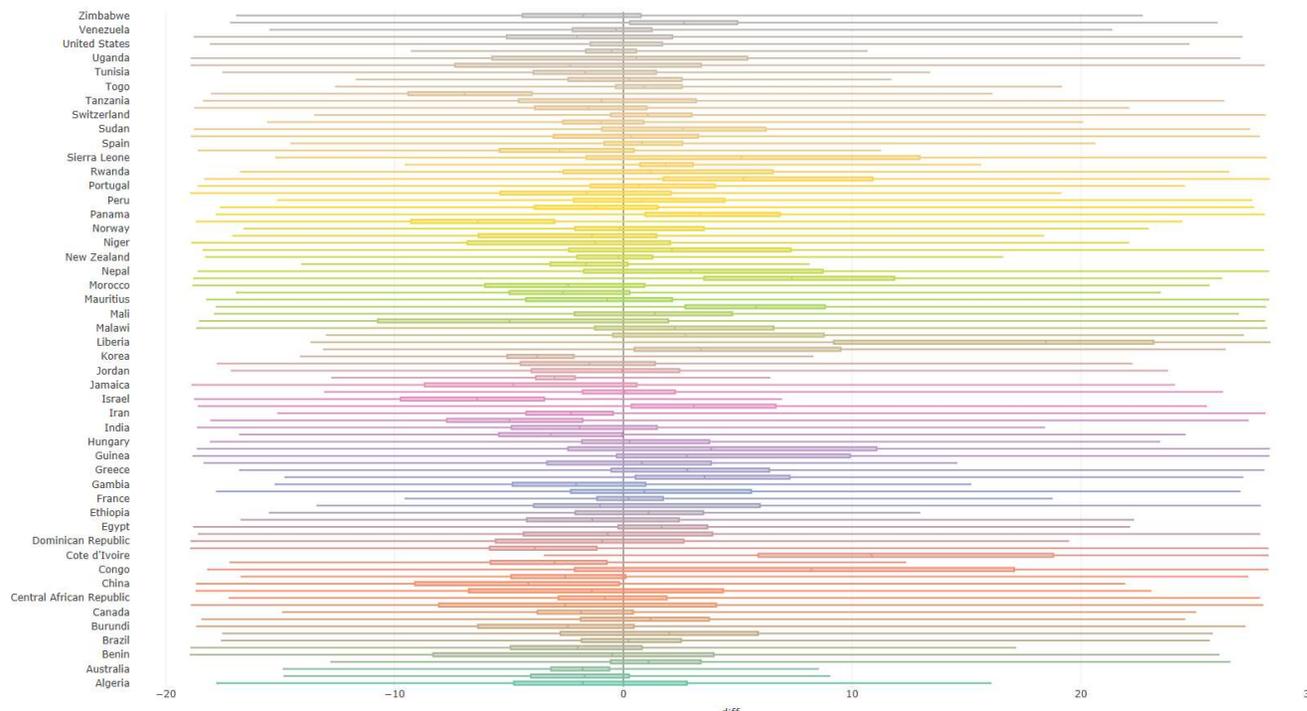


▪ <https://plot.ly/~HanxuehuiAIIB/3.embed>

GROWTH RATE DIFFERENCE BETWEEN LIGHT AND ELECTRICITY (ANNUALIZED %)

- Countries with a high value of median $R_{i,t}^{lh}$ (%):

Liberia (18.47),
 Cote d 'vote (10.85),
 Congo (8.22),
 Mozambique (7.36),
 and Sierra Leone (5.16).

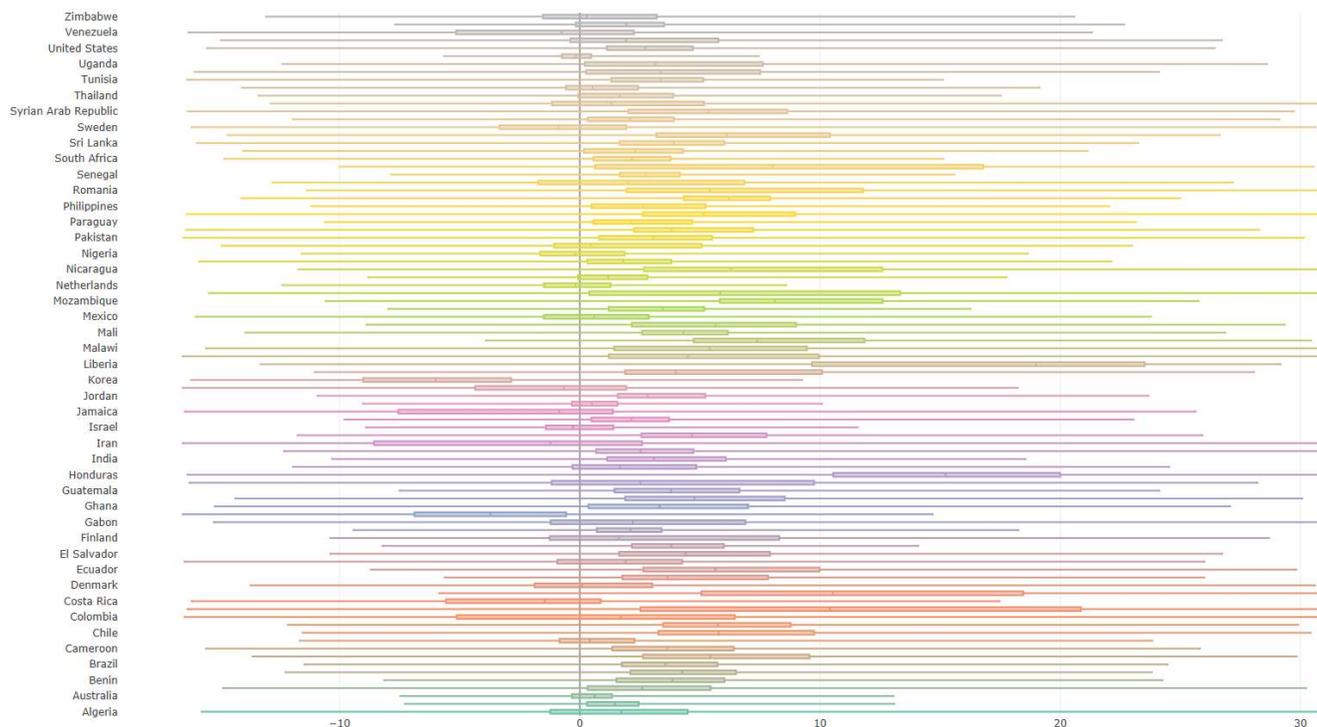


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GROWTH RATE DIFFERENCE BETWEEN LIGHT AND RAILS (ANNUALIZED %)

- Countries with a high value of median $R_{i,t}^{lh}$ (%):

Liberia (18.99),
Honduras (15.22),
Cote d 'vote (10.53),
Congo (10.41),
and Mozambique (8.12).



▪ <https://plot.ly/~HanxuehuiAIIB/7.embed>

OBSERVATIONS

- Rails are the most effective infrastructure investments, followed by electricity:
 - Most of the countries in the sample have positive median $R_{i,t}^{lh}$.
- Paved roads show large heterogeneities in terms of effectiveness:
 - Large negative $R_{i,t}^{lh}$ for countries such as Iran, Korea, Congo, and the Gambia.

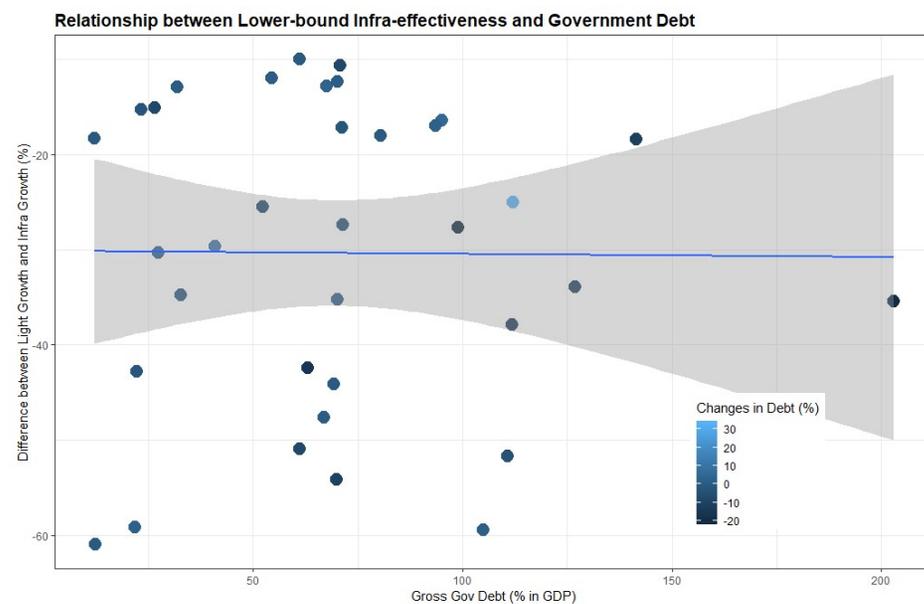
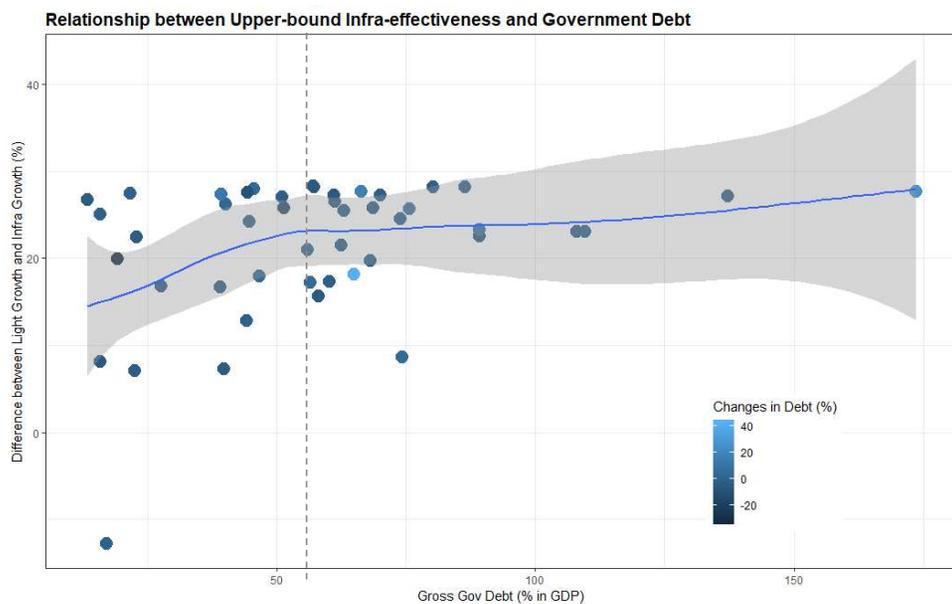
DEBT AND EFFECTIVENESS OF INFRASTRUCTURE I

Upper-bound and Lower-bound Approach

DEBT AND EFFECTIVENESS OF INFRA - PAVED ROAD

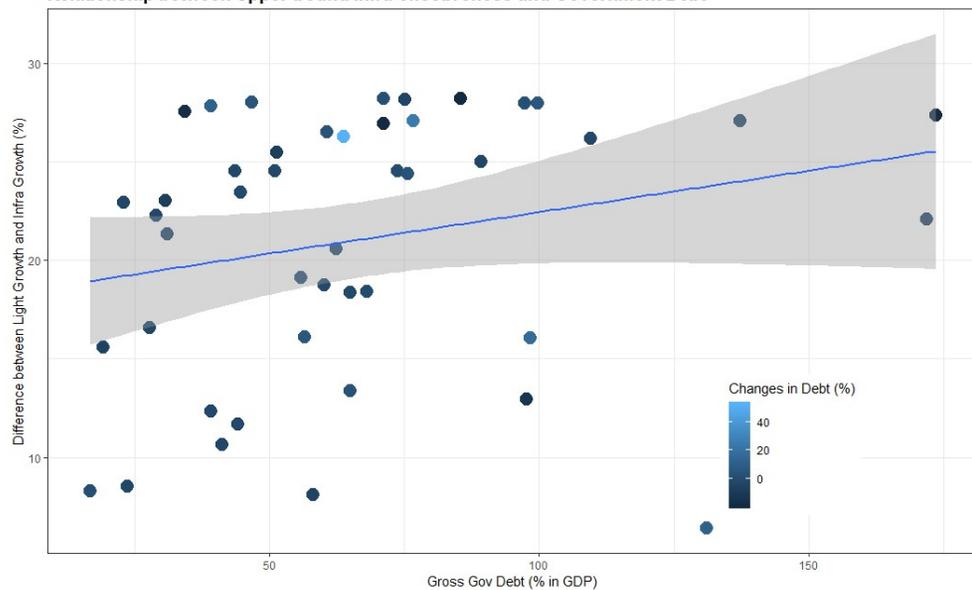
- Upper-bound: the maximum R_t^{lh} for each country i .

- Lower-bound: the minimum R_t^{lh} for each country i .

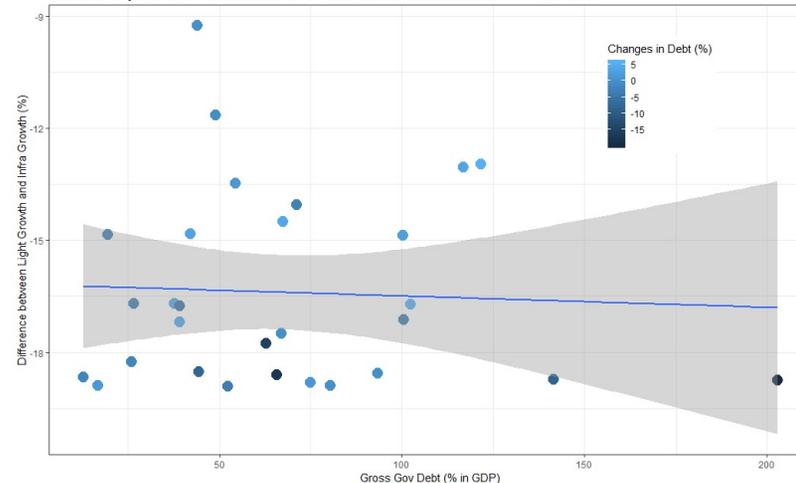


DEBT AND EFFECTIVENESS OF INFRA - ELECTRICITY

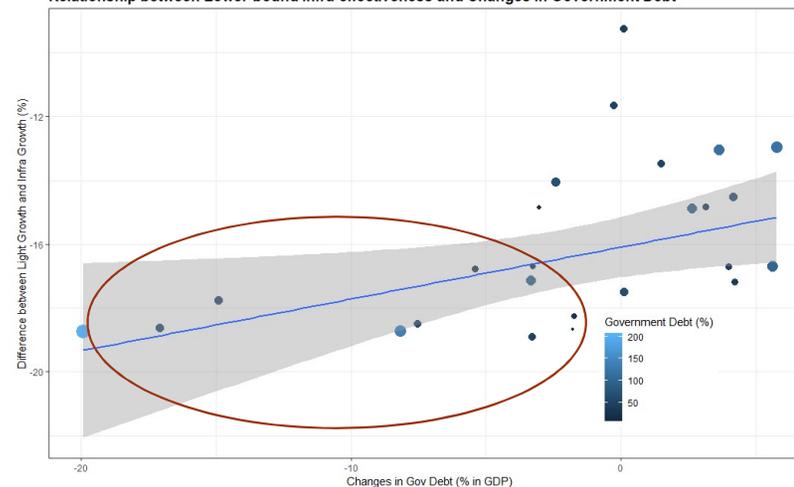
Relationship between Upper-bound Infra-effectiveness and Government Debt



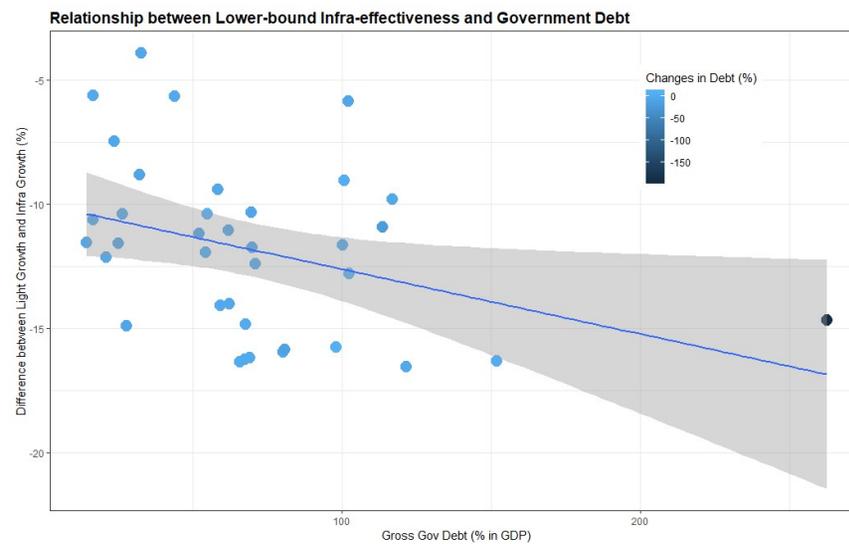
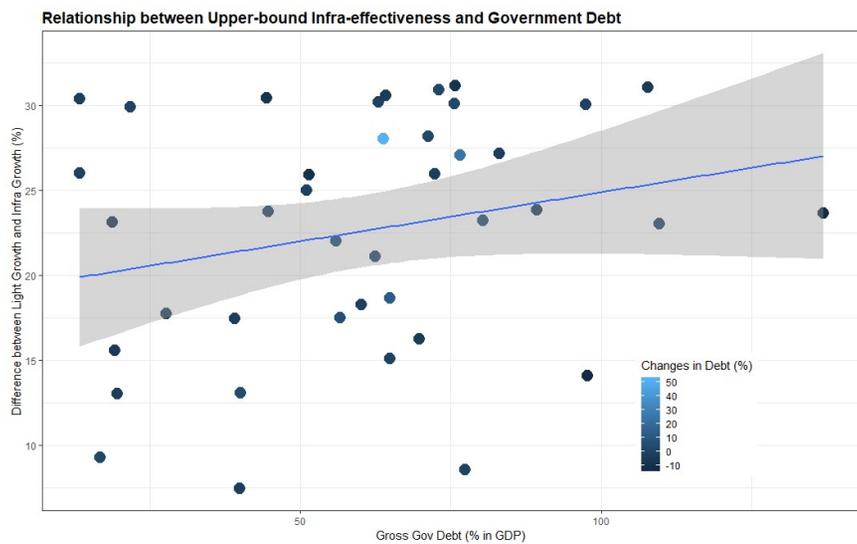
Relationship between Lower-bound Infra-effectiveness and Government Debt



Relationship between Lower-bound Infra-effectiveness and Changes in Government Debt



DEBT AND EFFECTIVENESS OF INFRA - RAILS



OBSERVATIONS FOR INFRA-INDUCED BRIGHTNESS OF LIGHTS AND DEBT

- Paved roads:
 - Upper-bound (best performing country-episodes):
 - Effectiveness of the investments **increases** along with government debt until a certain level;
 - Lower-bound (worse performing country-episodes):
 - No clear relationship.

- Electricity generated:
 - Upper-bound:
 - Effectiveness of the investments **increases** along with the government debt;
 - Lower-bound:
 - No clear relationship between the effectiveness of the investments and debt;
 - But sharp contractionary measure by reducing debt might **worsen** the worst.

- Rails:
 - Upper-bound:
 - Effectiveness of the investments **increase** along with the government debt;
 - Lower-bound:
 - High debt levels do associate with worse effectiveness of investment.

CAVEATS

- The economic benefits were not assessed based on the geographical locations of each project but at an aggregated level;
- The time coverage of the analysis is limited (1992-2013), which might not reflect medium or long term dynamics;
- No causal relationship was examined;
- This is a check of one-to-one association between economic return and infrastructure investments, which is not based on a comprehensive multivariate analysis.

DEBT AND EFFECTIVENESS OF INFRASTRUCTURE II

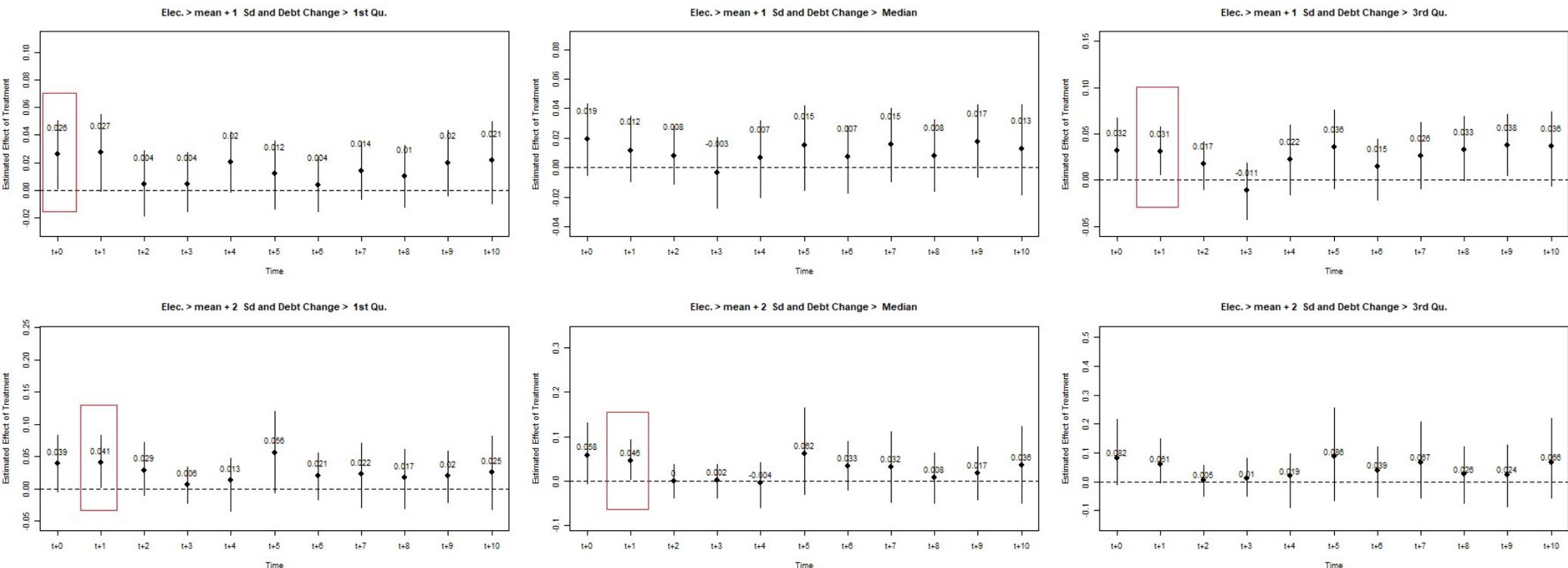
A matching method for causal inference with time series cross-sectional data

- A new matching method for causal inference with time series cross-sectional data by Imai, Kim, and Wang (2018) is used to assess the causality.
- The time coverage is extended to 1960 -2000, but with traditionally measured GDP;
- A causal relationship was examined;
- For the matching, the commonly accepted growth drivers, such as education, population, and initial income levels are controlled;
- Additionally, when one infrastructure investments are examined, the other types of infrastructures are controlled too.

THE TREATMENTS AND CONTROL VARIABLES:

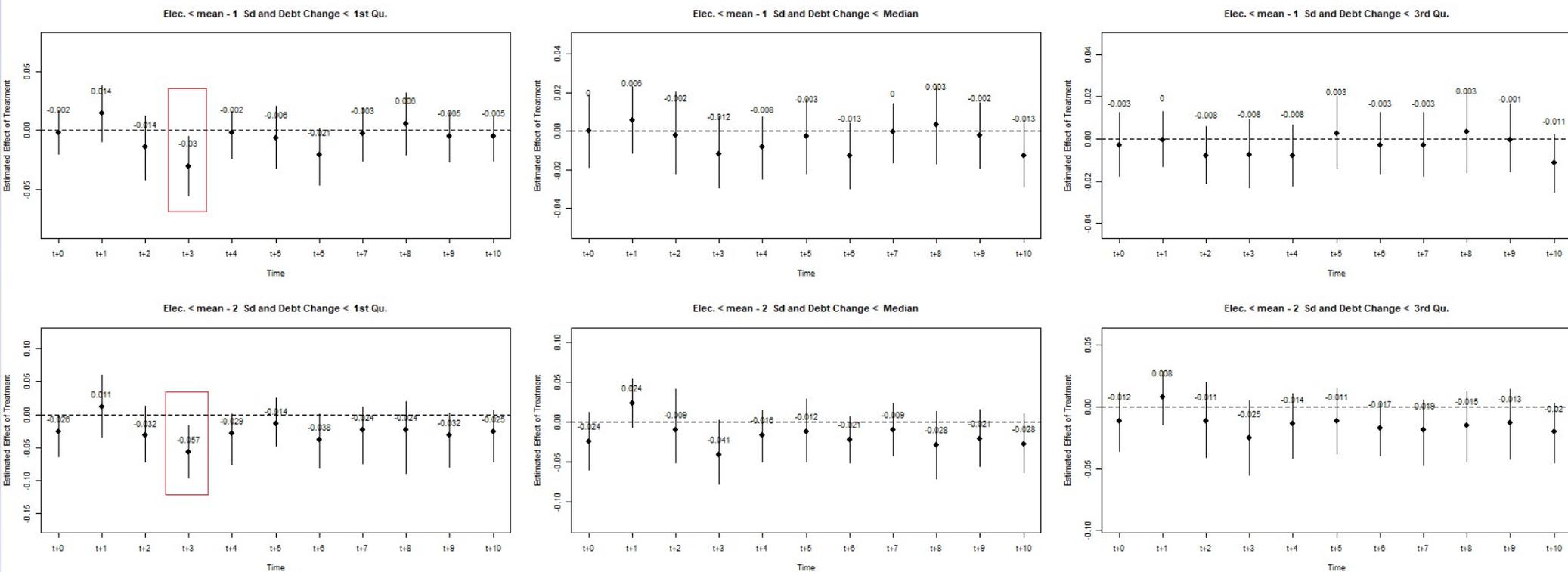
- **Treatment on infrastructures:**
 - The electricity generation or paved roads has experienced a positive shock with the size of mean + 1*SE or mean + 2*SE;
 - The electricity or paved roads has experienced a negative shock with the size of mean - 1*SE or mean - 2*SE;
- **Treatment on debts:**
 - A positive debt changes with the size of above 1 quartile, median, or 3rd quartile;
 - A negative debt changes with the size of below 1 quartile, median, and 3rd quartile.
- **Variables used in the matching:**
 - One period lagged years of schooling, government debt, electricity generation capacity, telephone lines, paved roads, railways, labor force population share, initial income level, and one- to three- period lagged economic growth.

THE POSITIVE ELECTRICITY TREATMENT TENDS TO HAVE “SUPPLEMENTAL” ROLES TO DEBT CHANGES TREATMENT



- Stronger positive electricity treatment would drive the economic growth with mild expansions in debts while weaker positive electricity might induce economic growth with strong expansionary debt measures.

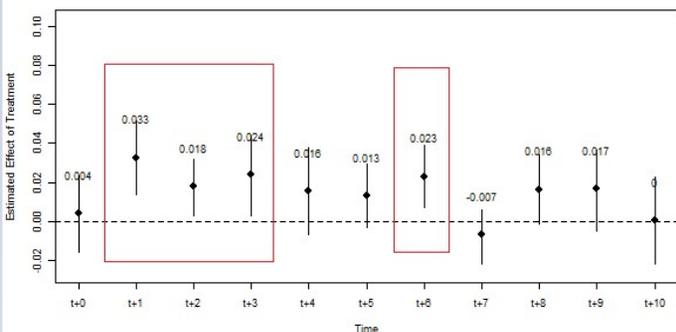
THE **NEGATIVE** ELECTRICITY TREATMENT ON **ELECTRICITY** GENERATION TENDS TO INDUCE SIGNIFICANT ECONOMIC DECLINE WHEN THE DEBT TREATMENT BELONGS TO THE CONTRACTIONARY END.



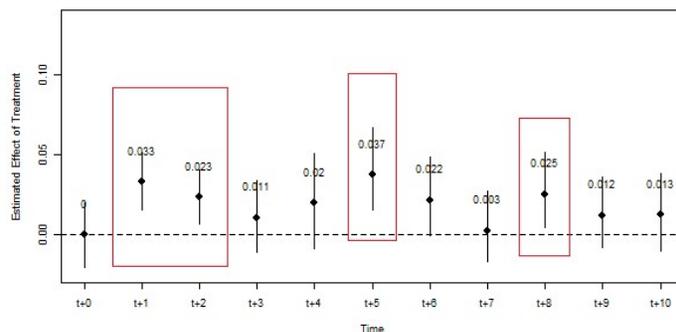
- It takes longer for the negative treatment to affect compared to the positive electricity treatment.

MODEST POSITIVE TREATMENTS ON PAVED ROADS TEND TO LEAD TO MULTIPLE PERIODS ECONOMIC GROWTH WHILE THE EXPANSIONARY DEBT TREATMENT WOULD LIMIT THE IMPACT.

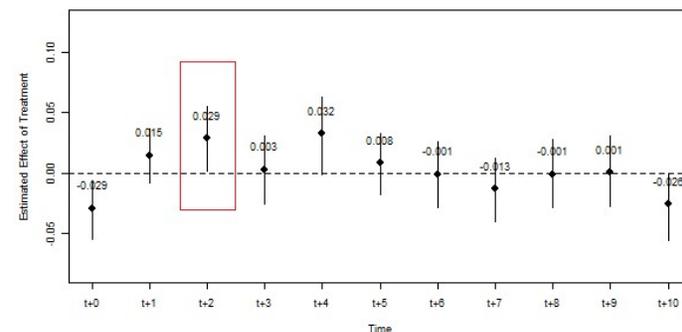
proads > mean + 1 Sd and Debt Change > 1st Qu.



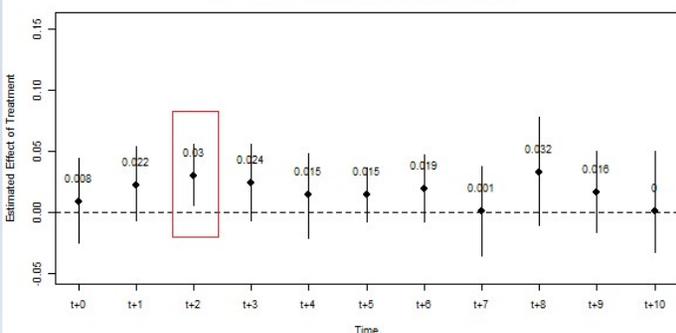
proads > mean + 1 Sd and Debt Change > Median



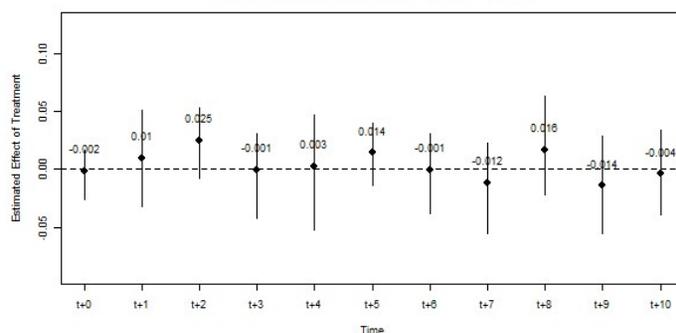
proads > mean + 1 Sd and Debt Change > 3rd Qu.



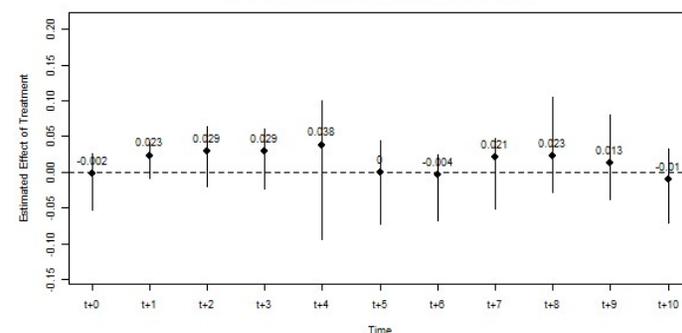
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proads > mean + 2 Sd and Debt Change > Median

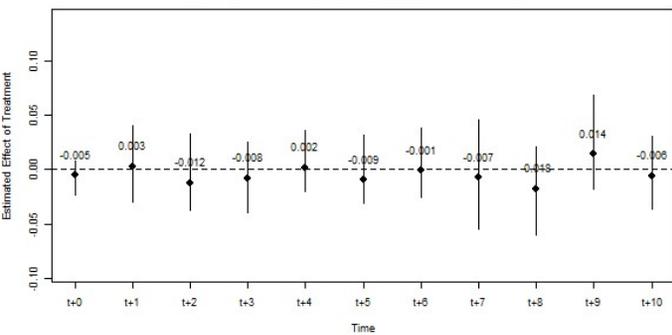


proads > mean + 2 Sd and Debt Change > 3rd Qu.

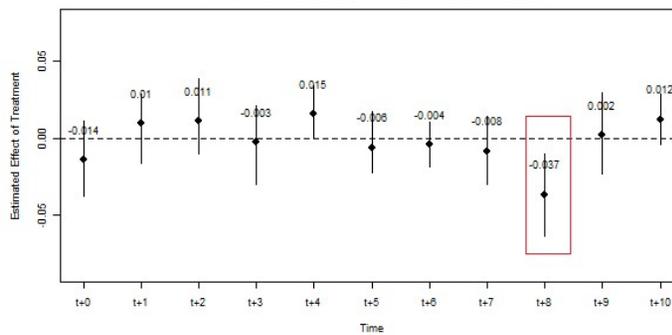


A MODEST **NEGATIVE** TREATMENT ON **PAVED ROADS** MIGHT LEADS TO ECONOMIC GROWTH WHILE THE DEBT TREATMENT IS EXPANSIONARY BUT NOT TOO EXTREME – THIS MIGHT THROUGH DEBT-INDUCED CONSUMPTION BALANCE OFF THE INVESTMENT CHANNEL;

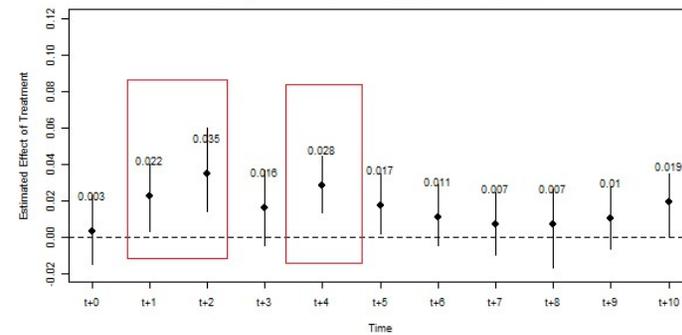
proads < mean - 1 Sd and Debt Change < 1st Qu.



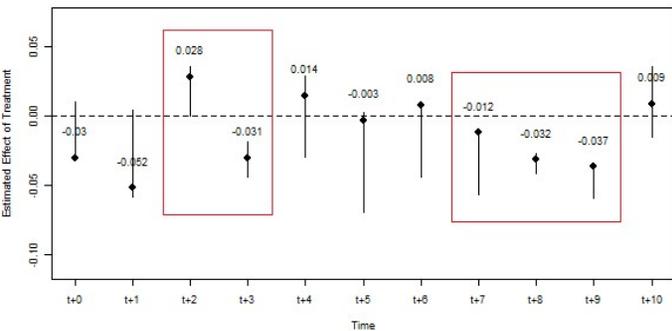
proads < mean - 1 Sd and Debt Change < Median



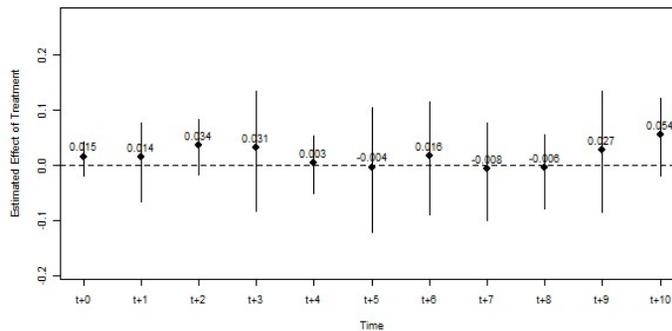
proads < mean - 1 Sd and Debt Change < 3rd Qu.



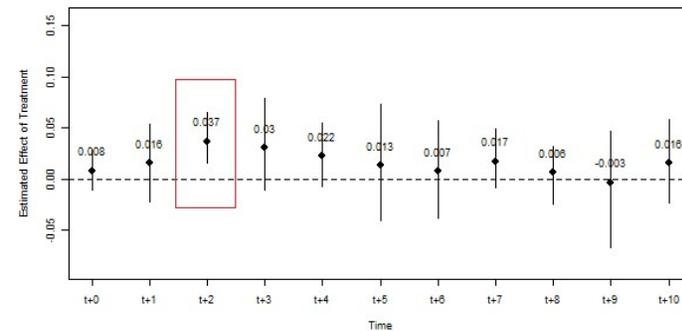
proads < mean - 2 Sd and Debt Change < 1st Qu.



proads < mean - 2 Sd and Debt Change < Median



proads < mean - 2 Sd and Debt Change < 3rd Qu.



But a strong negative treatment on paved roads will lead to economic decline while the debt treatment is very contractionary.

CONCLUSIONS

- Infrastructure investments needs an appropriate fiscal (debt) response to lead to economic growth;
- The impact of increases (positive treatments) in both electricity and paved roads are less conditioned on the debt changes while the impact of the decreases (the negative treatments) are highly conditioned on the debt changes;
- The economic impact of investment changes on paved roads last longer than on electricity;
- A sharp decline in paved roads would exert a large negative impacts on economic growth when the debt is in a strong contractionary process.

POLICY IMPLICATIONS

- **When countries choose the infrastructure investments, they have to consider the debt conditions:**
 - Modest investment increases in paved roads tends to generate larger and longer economic growth with less requirements on the debt conditions;
 - Strong investment increases in electricity tends to generate larger one-period economic growth;
 - Either modest or sharp decline in electricity investment would lead to economic decline in 3 years lead when the debt is in a strong contractionary process;
 - Only a sharp decline in paved roads together with a strong contractionary debt measure would lead to economic declines in the following years;
 - However, if a decline in paved roads and electricity investment is unavoidable, a expansionary (but not too extreme) debt would be helpful in terms to avoid the economic decline.

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