Long-Term Impacts of High Temperatures on Economic Productivity

Evidence from Earnings Data in Ecuador

Paul Carrillo, Ram Fishman, Jason Russ

George Washington University

Motivation

Short Term Impacts of High Temperature Anomalies

Motivation

Short Term Impacts of High Temperature Anomalies

Agricultural Production

(Deschenes and Greenstone, 2007; Lobell, Schlenker, and Costa-Roberts, 2011; Schlenker and Lobell, 2010; Guiteras, 2009; Fishman, 2011)

Labor supply and labor productivity in other sectors

(Hsiang, 2010; Dell et al, 2012; Sudarshan and Tewari, 2013; Zivin and Neidel, 2014; Deryugina and Hsiang, 2014)

Health

(Descheanes, Greenstone and Guryan 2009; Kovats et al, 2004; Schwartz, 2004; Basu and Samet, 2002; Mackenbach et al 1997; Burgess et al 2011)

Conflict and crime incidence

(Burke et al, 2009; O'Laughlin, 2012, Hsiang et al 2013; Ranson 2012; Fishman and Blakeslee 2013)

Motivation

Short Term Impacts of High Temperature Anomalies

+

Long Term Impacts of Early Life Stress on Adult Wellbeing

Almond and Currie (2011)

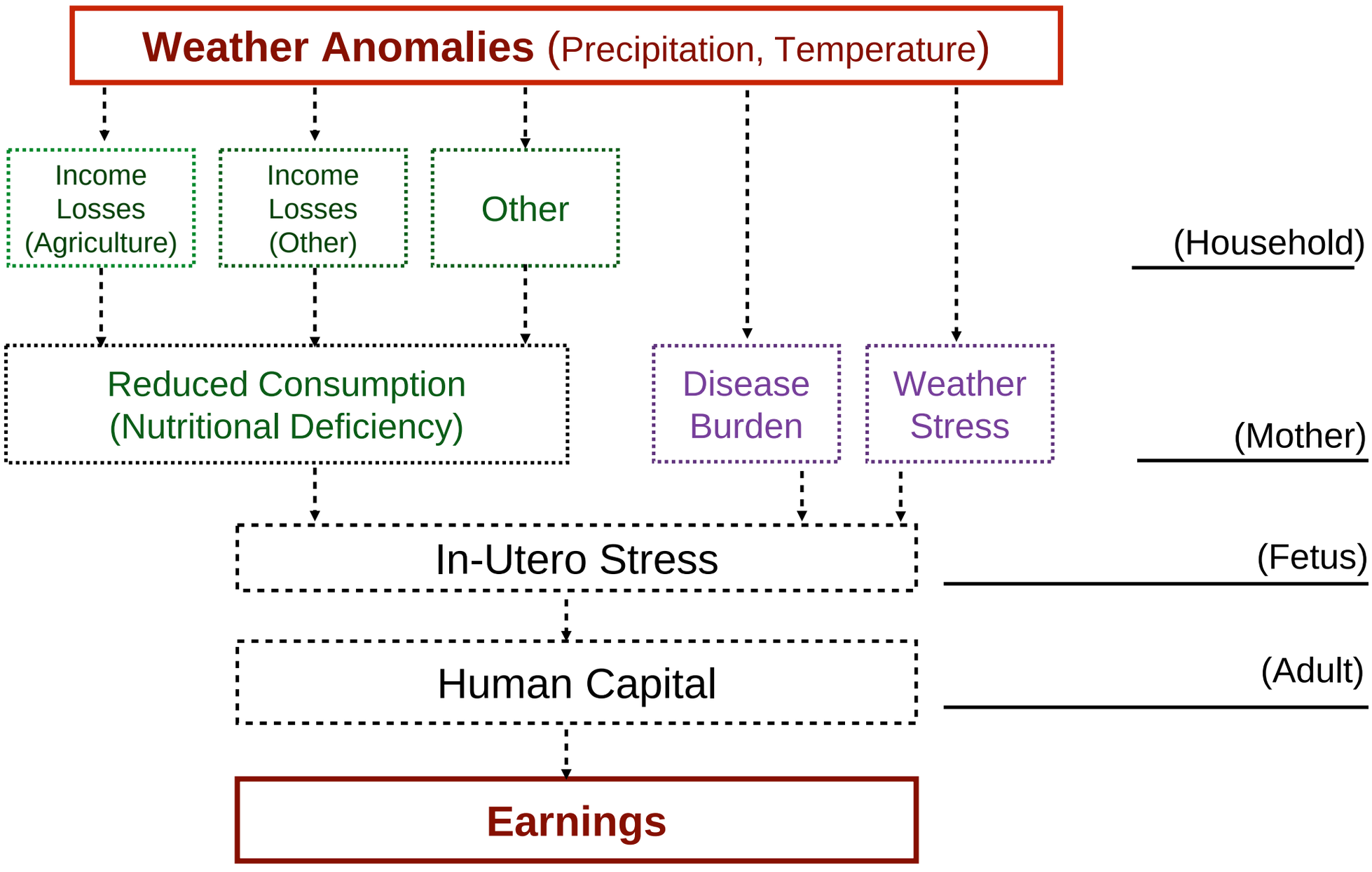
Motivation

Short Term Impacts of High Temperature Anomalies

+

Long Term Impacts of Early Life Stress on Adult Wellbeing

This Paper: Can Weather Shocks Early in Life Have Long Term Impacts on Adult's Wellbeing?


Weather Anomalies (Precipitation, Temperature)
Income Losses (Agriculture)
Income Losses (Other)
Other
Reduced Consumption (Nutritional Deficiency)
Disease Burden
Weather Stress
In-Utero Stress
Human Capital
Earnings
(Household)
(Mother)
(Fetus)
(Adult)

This Paper

Studies the long term effects of birth-year temperature on future earnings in Ecuador:

- Matches 2010 formal sector earnings to “Early life” temperature (and rainfall)

- Empirically documents a reduced-form, detrimental influence of hotter in-utero temperatures on formal sector earnings in Ecuador:

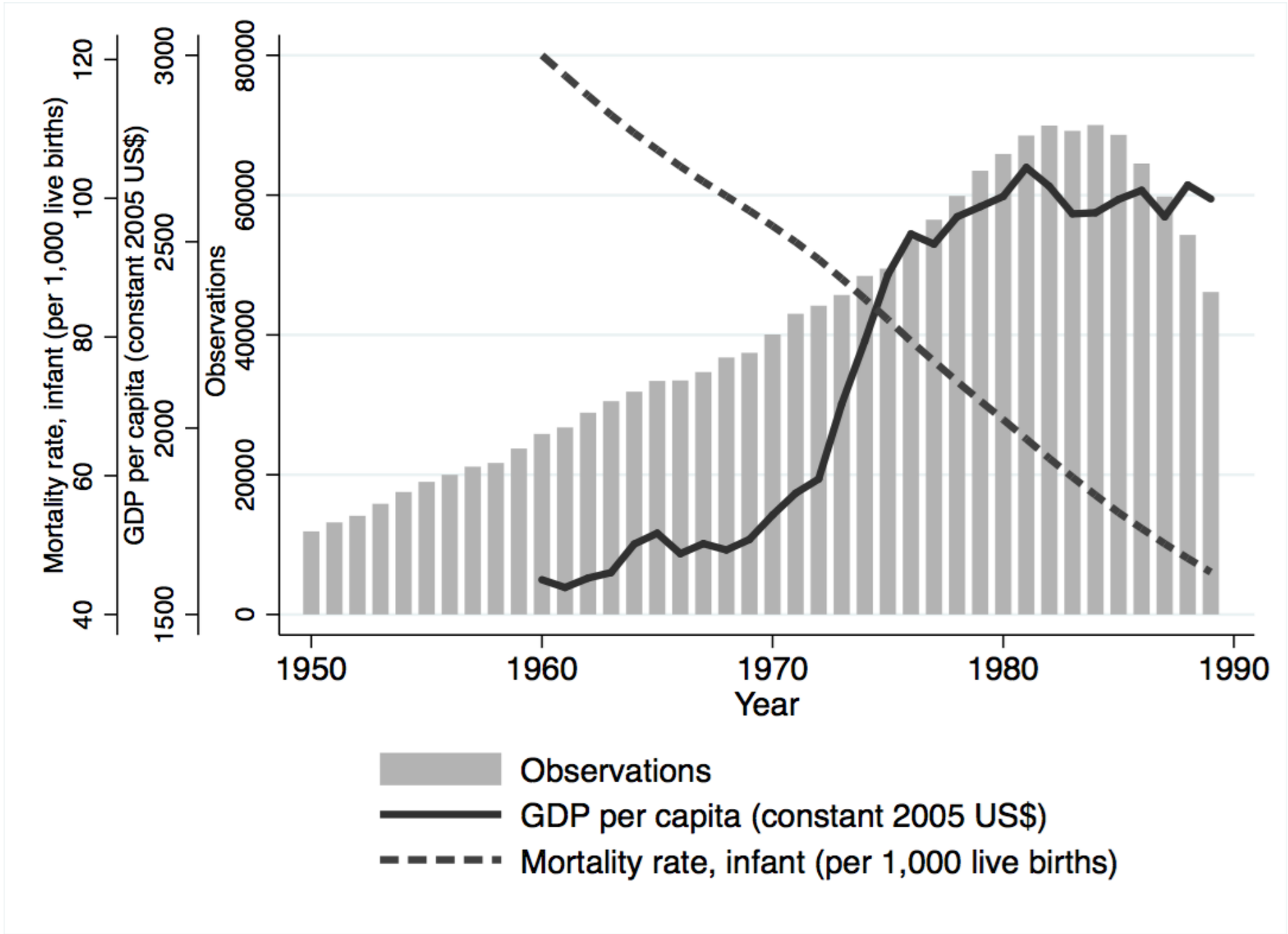
  1°C increase in in-utero temperature
  -> adult income lower by ~1% for females.

Contribution

- Several previous studies find long term impacts of precipitation shocks on subsistence farmers (Maccini and Yang 2008; Aguilar and Vicarelli 2011; Tiwari et al, 2013)

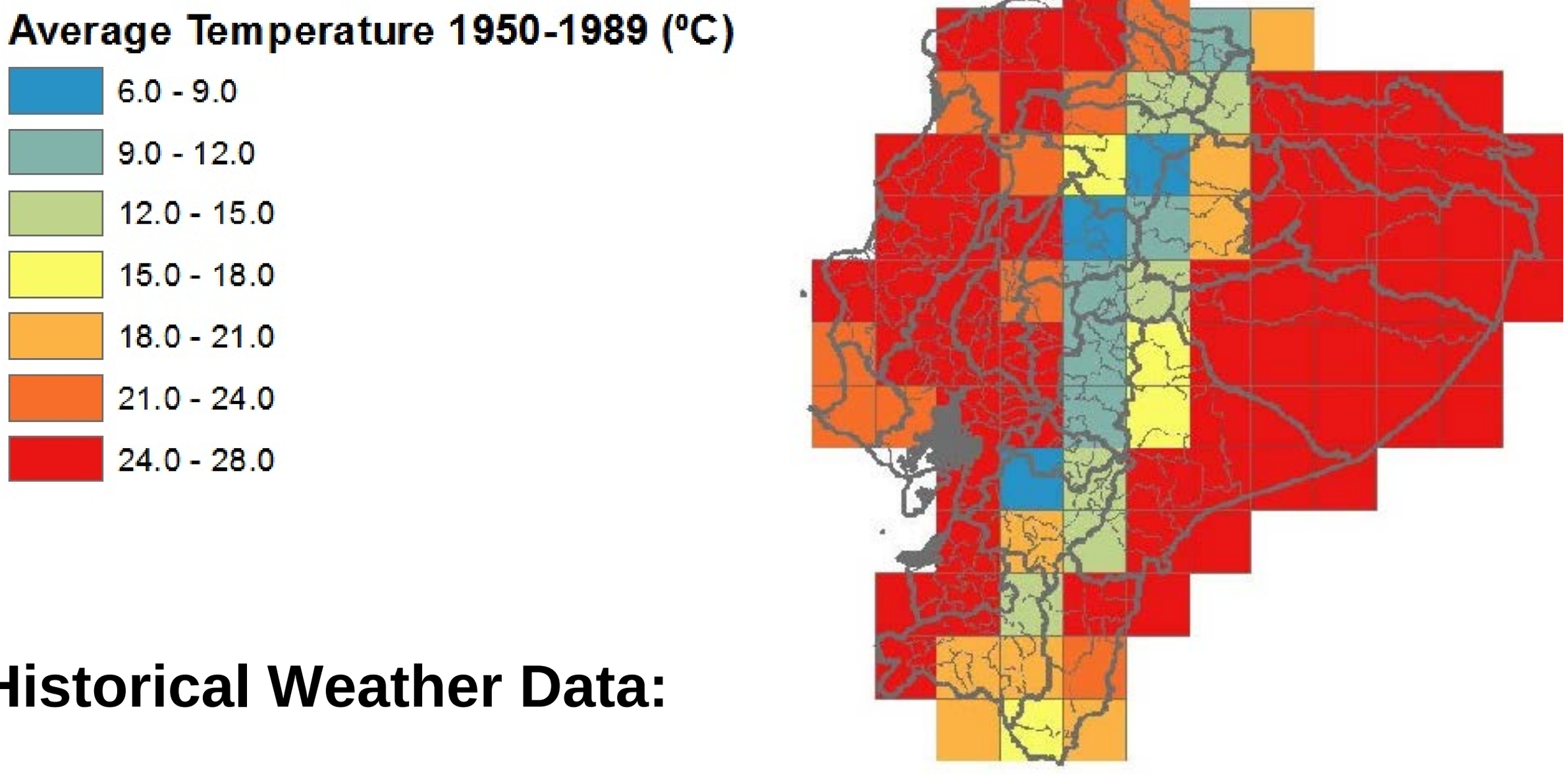
- This paper:

  - Temperature Shocks
  - Administrative earnings data
  - Sample is formally employed, wealthier and more urbanized and educated.



Earnings Data in Ecuador:

- Obtained from the Ecuadorian Tax Authority (“formal sector”)
- Merged with civil registry data
- 1.6 million individuals earning formal income in 2010 (2/3 males)
- Born between 1950 and 1989 (mean income $6,749)

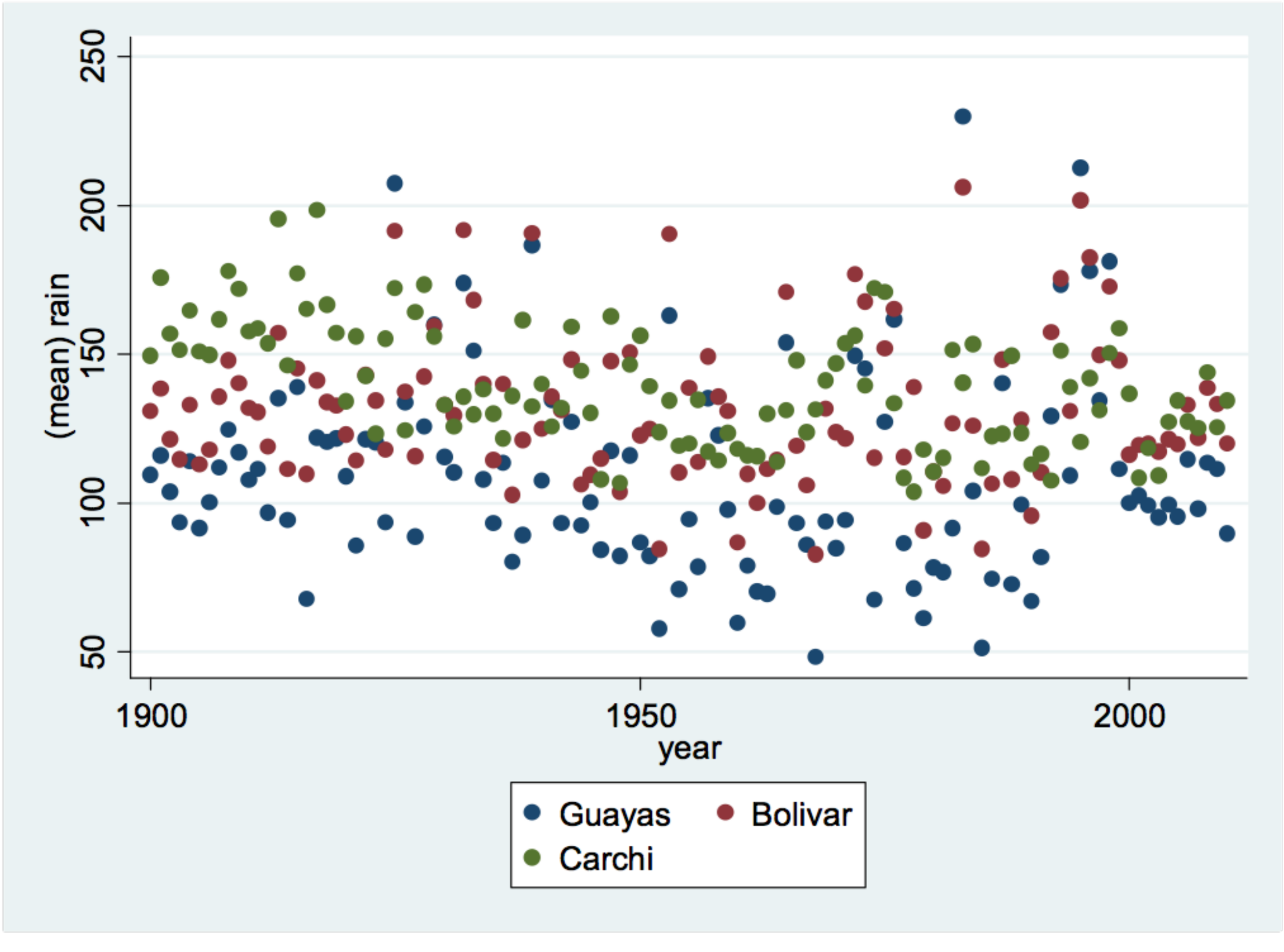


Historical Weather Data:

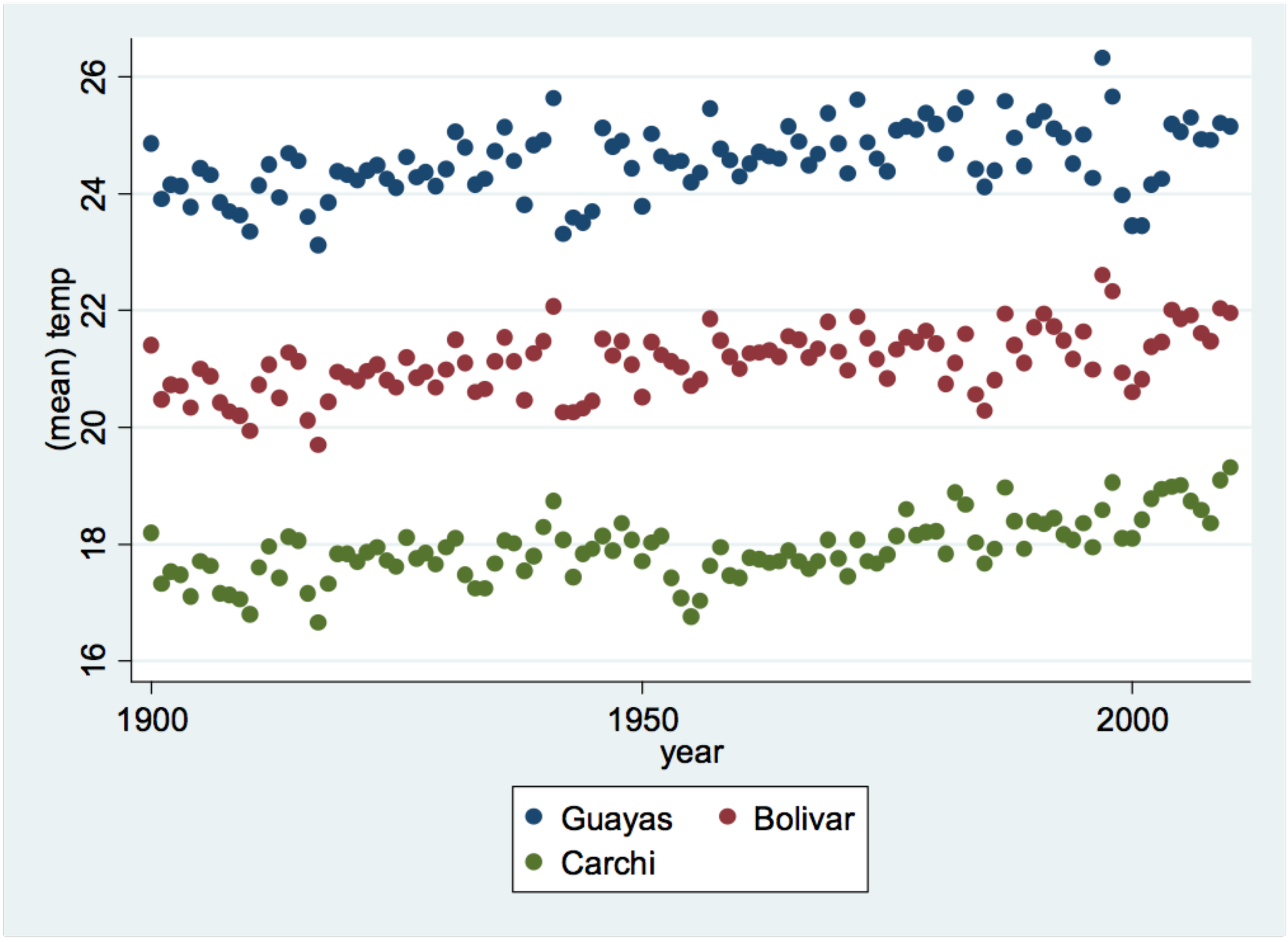
- Matsuura and Willmott (2012): Monthly average, gridded data (0.5 degree) of air temperature and rainfall

- Spatially averaged to administrative boundaries (24 provinces / 218 cantons)

Weather Data



Weather Data



Model Specification

$$ln(y_{icmy}) = \alpha_1 + \alpha_2 T^l_{cmy} + \alpha_3 T^f_{cmy} + \alpha_4 R^l_{cmy} + \alpha_5 R^f_{cmy} + f_p(t) + \gamma_{mc} + \theta_y + \varepsilon_i$$

Y_{icmy} : Income of individual i, born in canton c (23), in month m of year y

T^f_{cmy} and T^l_{cmy} : average temperature in canton of birth, 9 months before/after birth

R^f_{cmy} and R^l_{cmy} : average rainfall (cm) in canton of birth, 9 months before/after birth

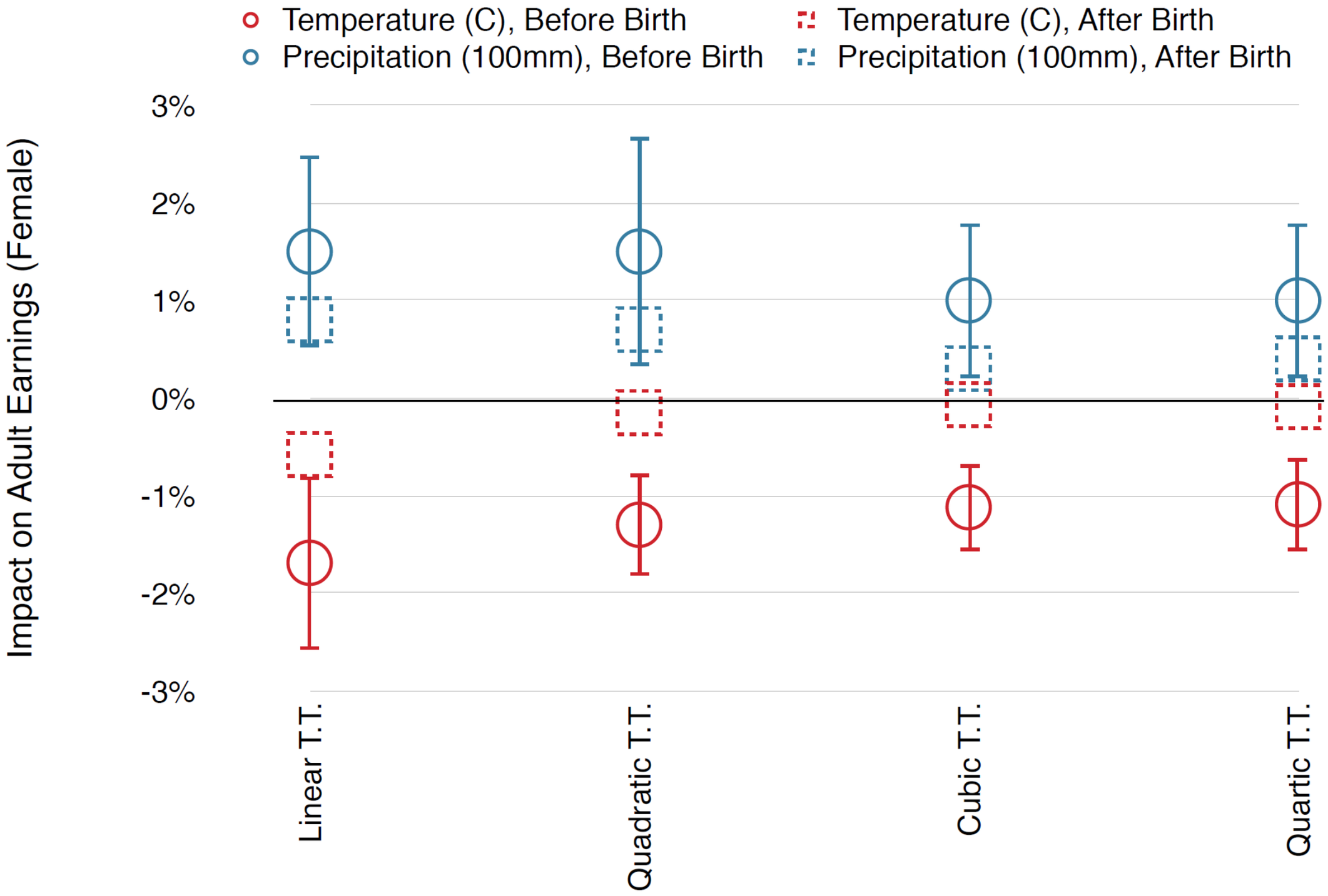
f(t): province specific time trend (ranging from linear to quartic specifications),

γ_{pc} month-canton fixed effects

θ_y :year fixed effects

Errors are clustered at various levels: province-year, region-year and province levels.

Results (Females Only)



Regression estimates for the impact of average monthly temperature (red, degrees centigrade) and precipitation (blue, 100mm) anomalies in-utero (circles) on (Log) adult earnings. Error bars represent 95% confidence intervals. For comparison, dotted square markers represent parallel coefficients for the impacts of average monthly weather during the 9 months following birth (confidence intervals are not shown, but all coefficients are statistically insignificant). Estimates from models with localized time trends ranging from linear to quartic are presented from left to right.

Regression Results (Females Only)

Dependent Variable: log income (2010)	(1)	(2)	(3)	(4)
Average Temperature, 9 months before birth (ºC)	-0.0169 (0.0045)*** (0.0070)** (0.0045)*** (0.0048)***	-0.0130 (0.0026)*** (0.0035)*** (0.0037)*** (0.0044)***	-0.0112 (0.0023)*** (0.0028)*** (0.0035)*** (0.0041)***	-0.0109 (0.0024)*** (0.0029)*** (0.0035)*** (0.0041)***
Average Temperature, 9 months after birth (ºC)	-0.0058 (0.0044) (0.0050) (0.0040) (0.0038)	-0.0015 (0.0029) (0.0049) (0.0031) (0.0032)	-0.0007 (0.0026) (0.0050) (0.0029) (0.0030)	-0.0009 (0.0025) (0.0046) (0.0029) (0.0031)
Average Rainfall, 9 months before birth (cm/month)	0.0015 (0.0005)*** (0.0006)** (0.0008)* (0.0008)*	0.0015 (0.0006)** (0.0006)** (0.0007)** (0.0007)**	0.0010 (0.0004)** (0.0005)** (0.0006) (0.0006)*	0.0010 (0.0004)** (0.0005)** (0.0006)* (0.0005)**
Average Rainfall, 9 months after birth (cm/month)	0.0008 (0.0006) (0.0005) (0.0006) (0.0006)	0.0007 (0.0005) (0.0005) (0.0005) (0.0006)	0.0003 (0.0006) (0.0006) (0.0005) (0.0005)	0.0004 (0.0006) (0.0006) (0.0005) (0.0005)
Province-Specific Time Trends	Linear	Quadratic	Cubic	Quartic
Year Fixed Effects	Y	Y	Y	Y
Month-Canton Fixed Effects	Y	Y	Y	Y
Observations	580,134	580,134	580,134	580,134
R-squared	0.1735	0.1743	0.1746	0.1746

Gender Disparities (No Effect for Males)

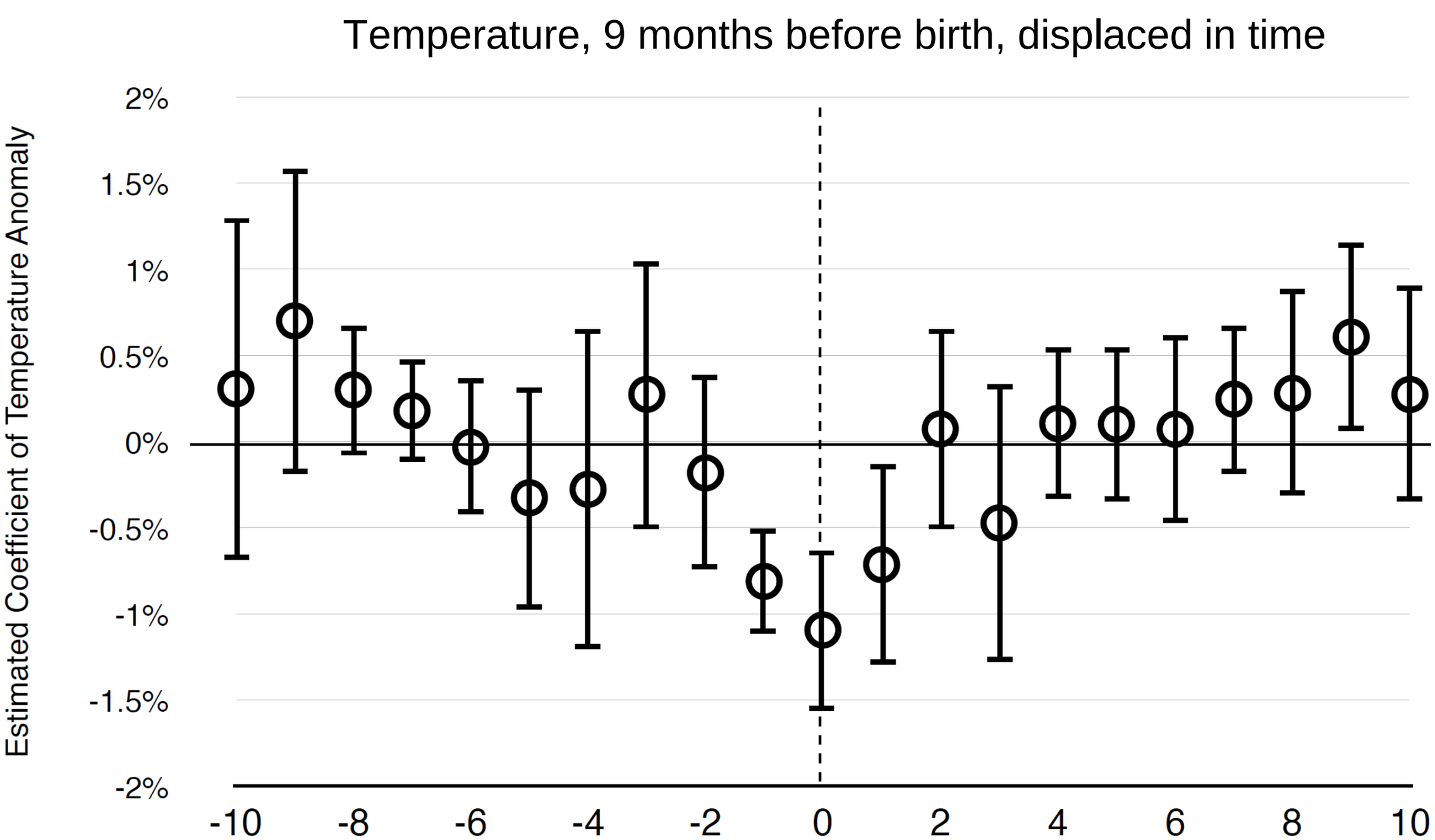
- Effects of in-utero temperatures on males and females statistically different.

- Possible explanations:

1. Gender-biased compensating investments? (Maccini and Yang, 2008, and references therein)

2. Males more likely to die in utero (Almond and Mazumder, 2011).

“Placebo” I

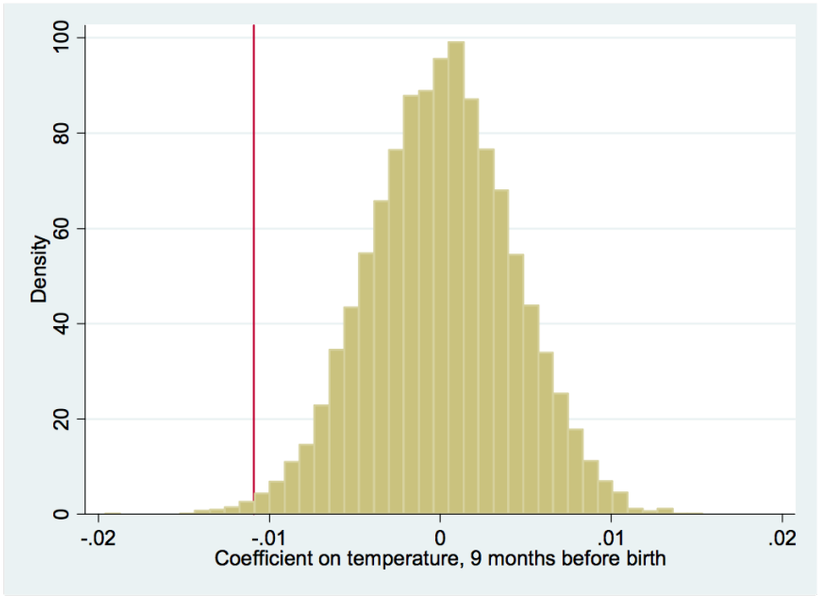


Notes: The graph contains coefficients and their respective 95% confidence intervals from estimating Equation (1), for females only, using various lags and leads of weather variables. The coefficients plotted are from separate regressions, and correspond to the variable indicating average temperature for the 9 months before birth. The x-axis indicates the number of lags and leads away from the true weather data, with negative values being lags, and positive values being leads.

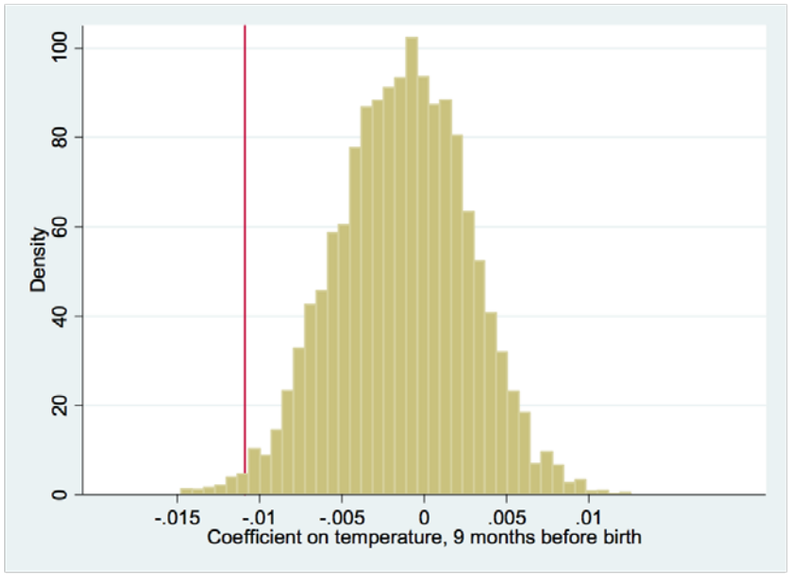
“Placebo” II

Randomly reshuffle weather observations across cohorts and re-estimate the regressions (Hsiang and Jina 2014)

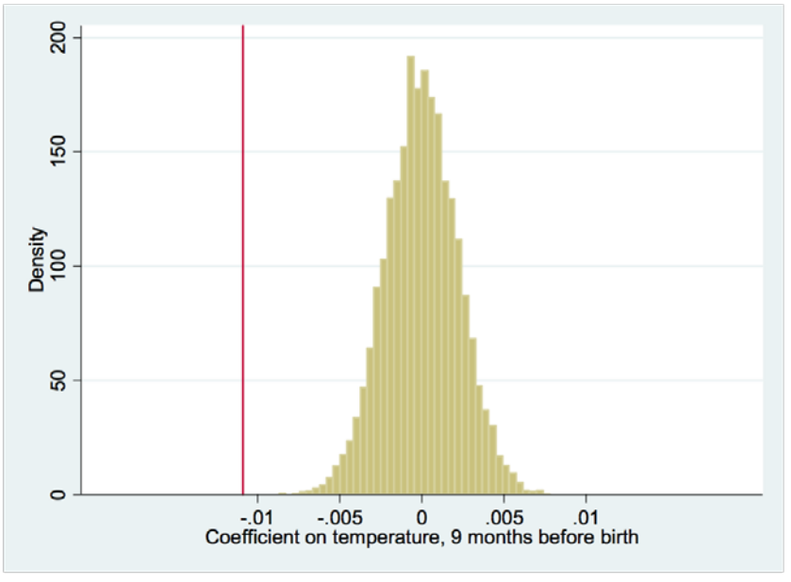
Across Time



Across Space



Across Space & Time



(10,000 estimates in each histogram)

Urban vs. Rural Impacts

Dependent Variable: log income (2010)	(1)	(2)	(3)	(4)
Average Temperature, 9 months before birth	-0.0131 (0.00786)	-0.0129** (0.00618)	-0.0116** (0.00541)	**-0.0101*** **(0.00505)**
Average Temperature, 9 months before birth *Urbanization Rate	-0.00710 (0.0101)	0.0000259 (0.00852)	0.00109 (0.00760)	**-0.00131** **(0.00729)**
Average Temperature, 9 months after birth	-0.00448 (0.00993)	-0.00620 (0.00806)	-0.00500 (0.00791)	-0.00313 (0.00755)
Average Temperature, 9 months after birth *Urbanization Rate	-0.00256 (0.0127)	0.00865 (0.0102)	0.00797 (0.0103)	0.00418 (0.0101)
Average Rainfall, 9 months before birth	0.00195** (0.000924)	0.00226** (0.000991)	0.00235** (0.00104)	**0.00237**** **(0.00105)**
Average Rainfall, 9 months before birth *Urbanization Rate	-0.000661 (0.00111)	-0.00132 (0.00123)	-0.00229* (0.00119)	**-0.00216*** **(0.00119)**
Average Rainfall, 9 months after birth	-0.00218 (0.00129)	-0.00126 (0.00117)	-0.000822 (0.00121)	-0.000860 (0.00121)
Average Rainfall, 9 months after birth *Urbanization Rate	0.00491*** (0.00174)	0.00309* (0.00157)	0.00180 (0.00186)	0.00208 (0.00182)
Province-Specific Time Trends	Quartic	Quartic	Quartic	Quartic
Year Fixed Effects	Y	Y	Y	Y
Month-Canton Fixed Effects	Y	Y	Y	Y
Observations	570,941	570,941	570,941	570,941
R-squared	0.173	0.174	0.175	0.175

Selection Concerns

Our sample: Formal workers in 2010

Can weather shocks affect survival rates, selection into formal sector, or migration before birth?

Biases in our estimated coefficient?

1. Selection through survival (-) (Almond and Curie, 2011; Maccini and Yang, 2008)

2. Selection into formal sector (-)

3. Migration before birth? (+ if wealthy)
(Feng et al, 2012; Feng et al, 2014; Bohra-Mishra et al, 2014; Fishman et al 2015)

Selection into Formal Sector

Dependent Variable: =1 if earned formal sector income, 2010	(1) Full Population	(2) Females Only	(3) Males Only
Average Temperature, 9 months before birth (ºC)	-0.0006 (-1.08)	-0.00065 (-1.19)	-0.00055 (-0.64)
Average Temperature, 9 months after birth (ºC)	0.000148 (0.24)	0.000839 (0.95)	-0.00063 (-1.31)
Average Rainfall, 9 months before birth (cm/month)	0.000158 (1.51)	0.000109 (1.16)	0.000203 (1.59)
Average Rainfall, 9 months after birth (cm/month)	0.000171* (2.00)	0.000166* (2.01)	0.000162 (1.37)
Province-Specific Time Trends	Quadratic	Quadratic	Quadratic
Year Fixed Effects	Y	Y	Y
Month-Province Fixed Effects	Y	Y	Y
Observations	8,159,284	4,078,650	4,080,634
R-squared			

* p<0.1, ** p<0.05, *** p<0.01

Notes: Sample includes individuals born between 1950 and 1989 who were registered with the Ecuadorian Civil Registry in 2010. Each column presents coefficients (standard errors) from a separate regression estimated using OLS. Standard errors in parentheses are clustered at the province level. Column (1) includes the full population, while columns (2) and (3) only include females and males, respectively. Each observation is an individual who was registered with the Ecuadorian Civil Registry in 2010. The dependent variable is equal to 1 if the individual earned any formal sector income in 2010, and 0 otherwise.

Impact on Cohort Size

Dependent Variable: log(number of individuals born in each month, year, and canton cohort)	(1) Full Sample	(2) Females Only	(3) Males Only
Average Temperature, 9 months before birth (ºC)	-0.0264** (-2.18)	-0.0221* (-1.85)	-0.0300** (-2.74)
Average Temperature, 9 months after birth (ºC)	-0.0154 (-1.40)	-0.0162 (-1.64)	-0.0103 (-0.91)
Average Rainfall, 9 months before birth (cm/month)	-0.00109 (-0.77)	-0.0009 (-0.67)	-0.00134 (-0.88)
Average Rainfall, 9 months after birth (cm/month)	-0.00144 (-1.13)	-0.00155 (-1.16)	-0.0012 (-1.06)
Province-Specific Time Trends	Quartic	Quartic	Quartic
Year Fixed Effects	Y	Y	Y
Month-Canton Fixed Effects	Y	Y	Y
Observations	67,157	65,994	65,799
R-Squared	0.894	0.858	0.878

* p<0.1, ** p<0.05, *** p<0.01

Notes: Sample includes individuals born between 1950 and 1989 who were in the Ecuadorian civil registry in 2010. Each column presents coefficients (standard errors) from a separate regression estimated using OLS. Standard errors in parentheses are clustered at the province level. Column (1) includes the full population, while columns (2) and (3) only include females and males, respectively. Each observation is a month, year, and canton cohort in which at least one individual in the civil registry was born.

Migration by better offs?

- Weather induced migration
- Evidence against this hypothesis:
  - Run cohort model at the canton and province level.
  - Migration is more likely to be within a province, so negative effects of temperature on cohort size should disappear at the prov. level.
  - This is NOT the case

Conclusions

- Economically significant relationship between in-utero temperature and adult income for females
- 1°C warmer period 9 months before birth reduces income by 1.1-1.7%
- Did Climate Change already create long-term (pipeline) productivity losses?
- Mechanism requires further investigation