# Economics 270c
Graduate Development Economics

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# Economics 270c

Graduate Development Economics

Lecture 14 – April 28, 2009

Macroeconomic growth empirics

Lecture 1: Global patterns of economic growth and development (1/20)

Lecture 2: Inequality and growth (1/27)

The political economy of development

Lecture 3: History and institutions (2/3)

Lecture 4: Corruption (2/10)

Lecture 5: Patronage politics (2/17)

Lecture 6: Democracy and development (2/24)

Lecture 7: War and Economic Development (3/3)

Lecture 8: Economic Theories of Conflict (3/10) – Guest lecture by Gerard Padro

Human resources

Lecture 9: Human capital and income growth (3/17)

Lecture 10: Increasing human capital (3/31)

Lecture 11: Labor markets and migration (4/7)

Lecture 12: Health and nutrition (4/14)

Lecture 13: The demand for health (4/21)

Other topics

Lecture 14: Environment and development (4/28)

Lecture 15: Resource allocation and firm productivity (5/5)

Additional topics for the development economics field exam

-- Ethnic and social divisions

-- The Economics of HIV/AIDS

- Grading:
  Four referee reports – 40%

  Two problem sets – 20%

  Research proposal – 30%
  → Due next Tuesday May 5

  Class participation – 10%

  Last lecture next Tuesday May 5th – pizza and beer/soda at LaValls after class (4 pm)

# Lecture 14 outline

(1) Environment, climate change and economic development

(2) Air pollution and health outcomes (Jayachandran 2006)

(3) Does economic development lead to environmental degradation? (Foster and Rosenzweig 2003)

(4) Property rights institutions and environmental amenities (Kremer et al. 2009)

# (1) Environment and development

- What is the impact of environmental pollution (air, water) on health and economic outcomes? What distributional consequences? (Jayachandran 2006)
- Does economic growth lead to the deterioration of environmental resources? Is there a trade-off between growth / poverty reduction and the environment? (Foster and Rosenzweig 2003)
- Which property rights institutions are best for providing environmental amenities? (Kremer et al 2009)
- How will climate change affect economic development?

# (1) Environment and development

- Why is studying the environment any different from other sectors in development economics?

  -- Externalities / spillovers are central (e.g., water pollution in China)

  -- Information asymmetries are often particularly severe (e.g., arsenic poisoning in Bangladeshi ground water)

  -- The possible extinction of entire animal and plant species could be extremely costly for future generations (e.g., pharmaceutical development)

- How is it similar? Relates to discussions of institutions / corruption (e.g., Paulina Oliva's work on Mexico smog check centers), health, industrialization, etc.

# (1) Climate change and development

- Global climate change will shift around current patterns of rainfall and temperature. Some areas will become hotter (drier) and others cooler (wetter)

- Current predictions indicate that several LDC regions could be adversely affected: West Africa will become increasingly hot and dry. Bangladesh may suffer more frequent floods

- Integrate these climate predictions with existing models to simulate future economic trajectories for different regions / countries

# (1) The IPCC4 Climate Projections

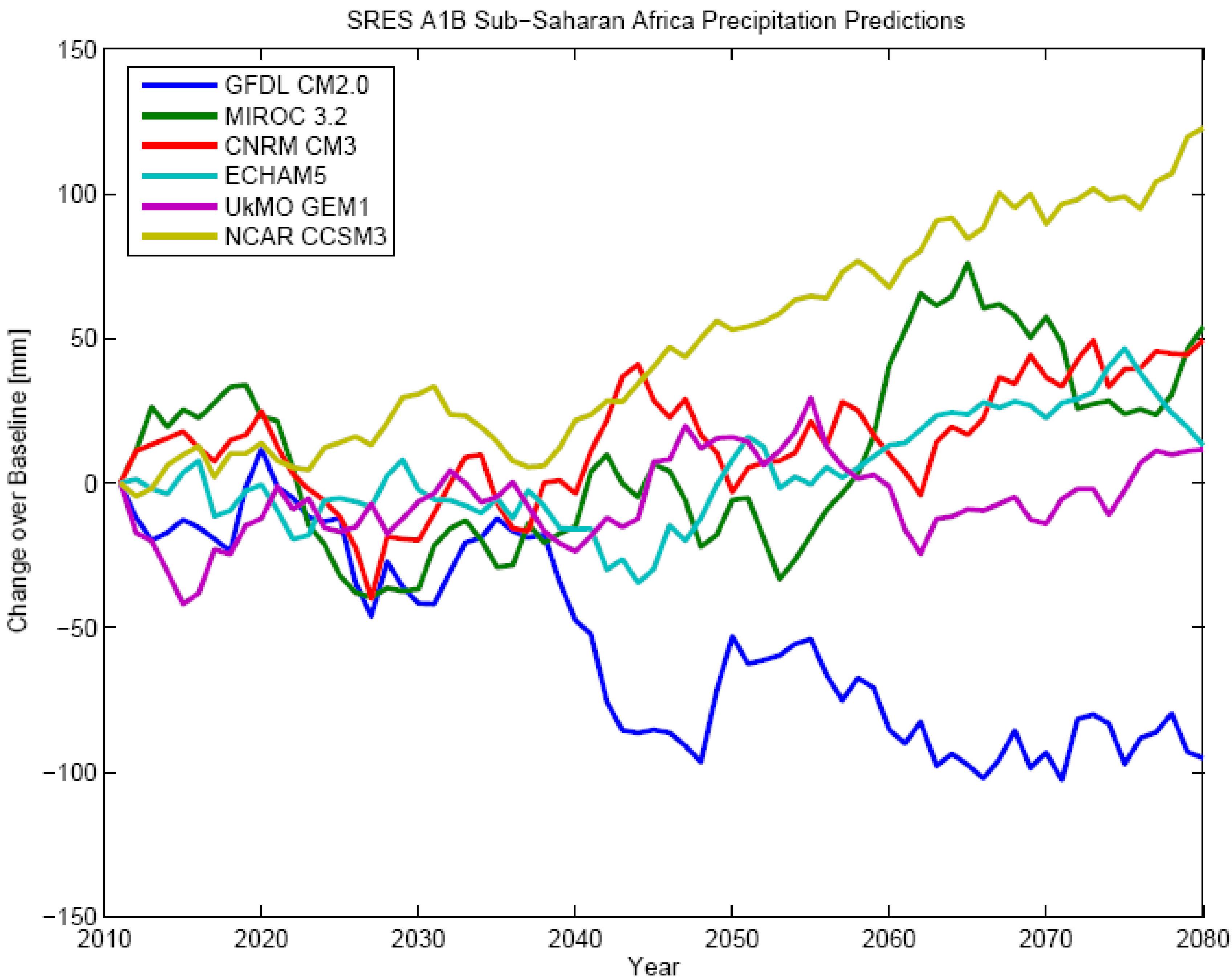
- There is a growing consensus that average global temperature is increasing and will continue to do so

  -- The Intergovernmental Panel on Climate Change (IPCC) combines the evidence and presents projections

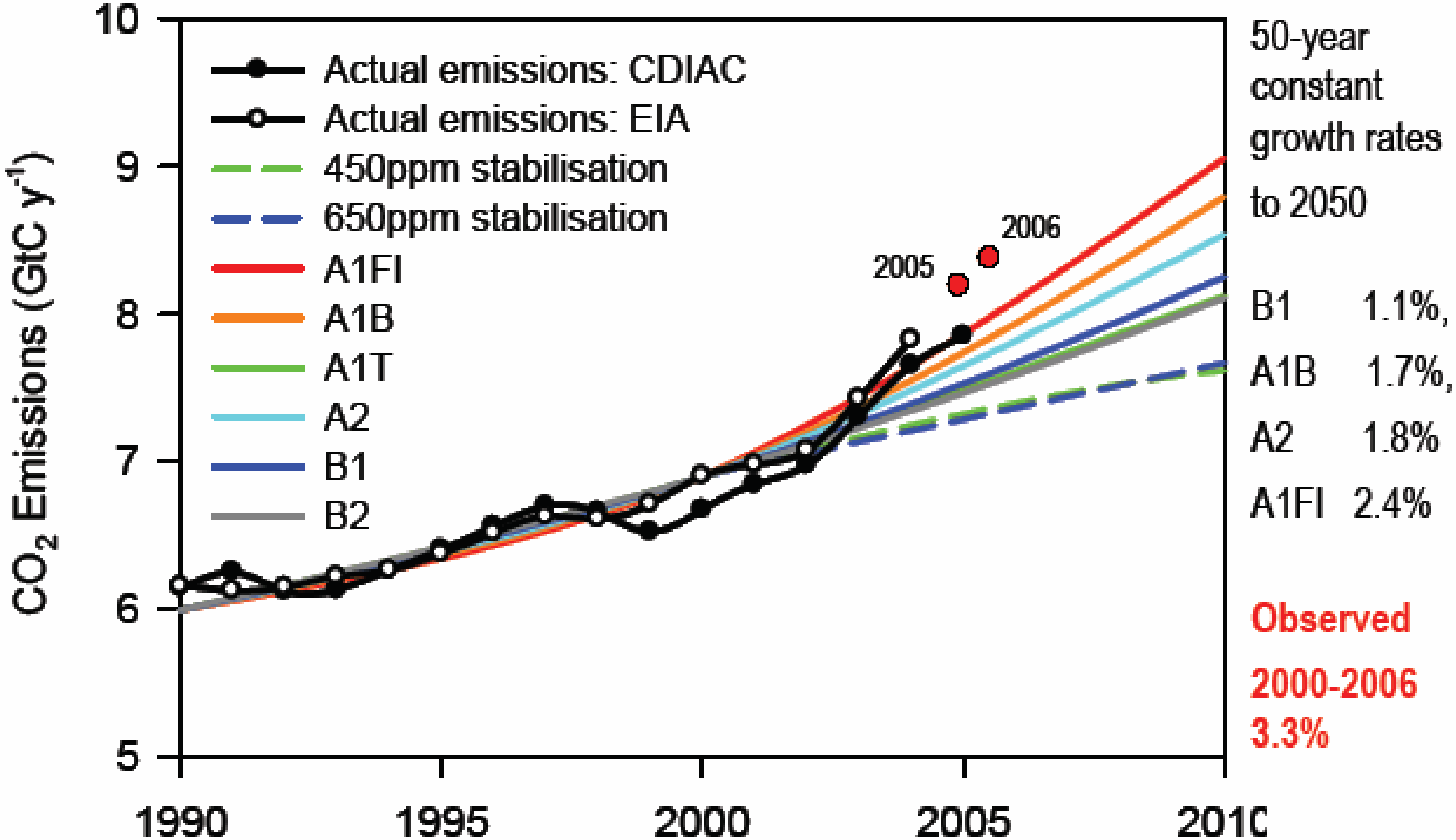
- Over 20 leading climate models (e.g., GFDL CM2.0, MIROC 3.2, CNRM CM3, ECHAM5, UkMO GEM1, NCAR CCSM3), with different $CO_2$ emission scenarios, including “moderate” (A1B) and “severe” (A2)

- The models are relatively consistent in predicting rising global temperatures over the next century

  -- Precipitation projections across these leading climate models are highly heterogeneous


SRES A1B Sub−Saharan Africa Precipitation Predictions
GFDL CM2.0
MIROC 3.2
CNRM CM3
ECHAM5
UkMO GEM1
NCAR CCSM3
Change over Baseline [mm]
150
100
50
0
−50
−100
−150
2010
2020
2030
2040
2050
2060
2070
2080
Year

# Trajectory of Global Fossil Fuel Emissions

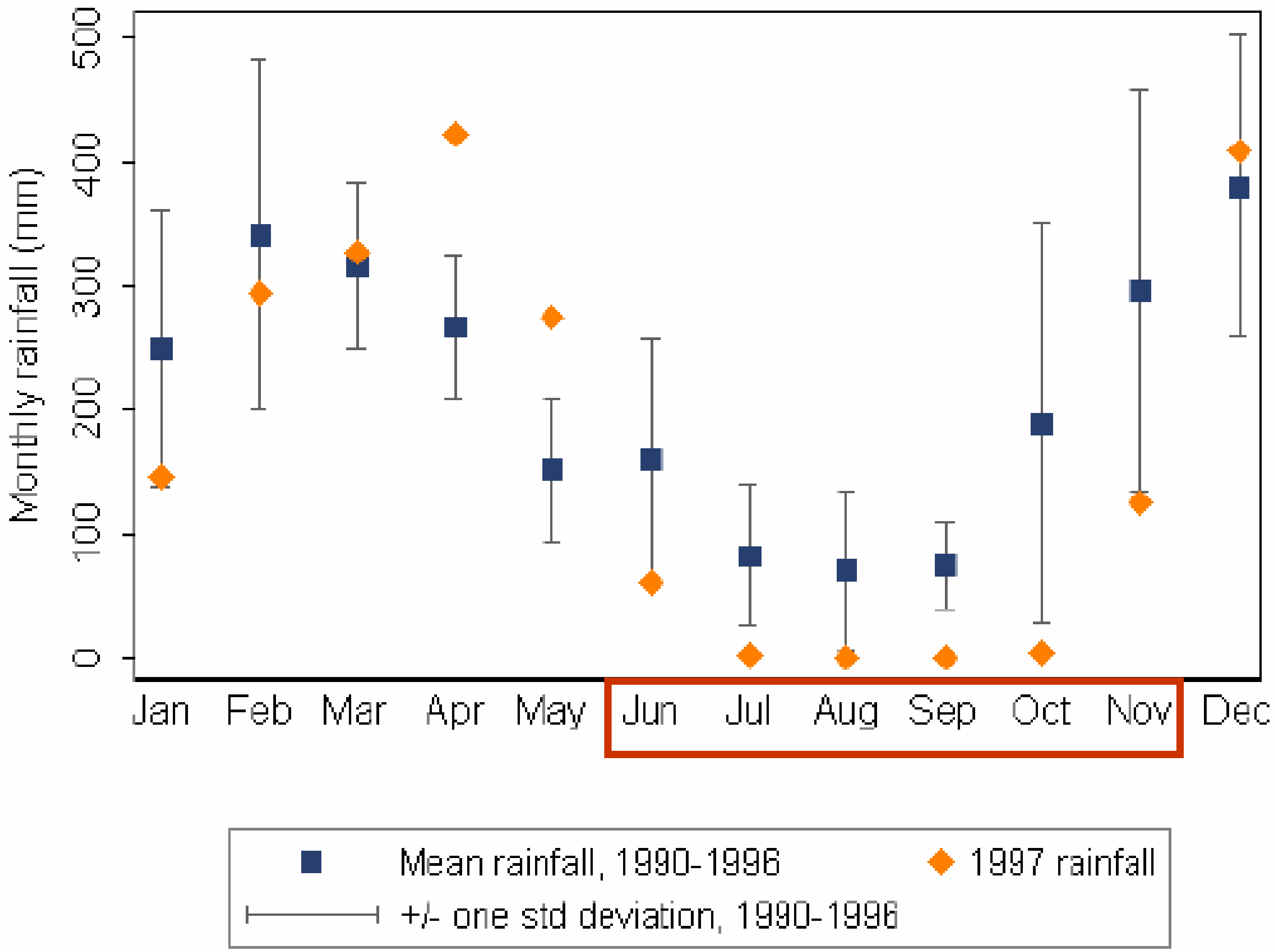



Raupach et al. 2007, PNAS; Canadell et al. 2007, PNAS

# (2) Jayachandran (2006)

- There were massive wildfires (set off by commercial logging companies) in Indonesia in late 1997
- The fire followed several months of abnormally low rainfall in an El Niño year that led to strange weather in many other parts of world (dry season flooding in Kenya)

Figure 1: Rainfall at Palembang Airport meteorological station, South Sumatra, 1990-97



# (2) Jayachandran (2006)

- There were massive wildfires (set off by commercial logging companies) in Indonesia in late 1997

- The fire followed several months of abnormally low rainfall in an El Niño year that led to strange weather in many other parts of world (dry season flooding in Kenya)

- Smoke blanketed much of Indonesia (and neighbors) at particulate matter concentrations far above safe levels: air pollution exceeded the $PM_{10}$ EPA standard of 150 $\mu g/m^3$ (not to be exceeded more than one day per year) for months at a time → what impact on infant mortality?

Figure 2: Satellite images of smoke over Indonesia

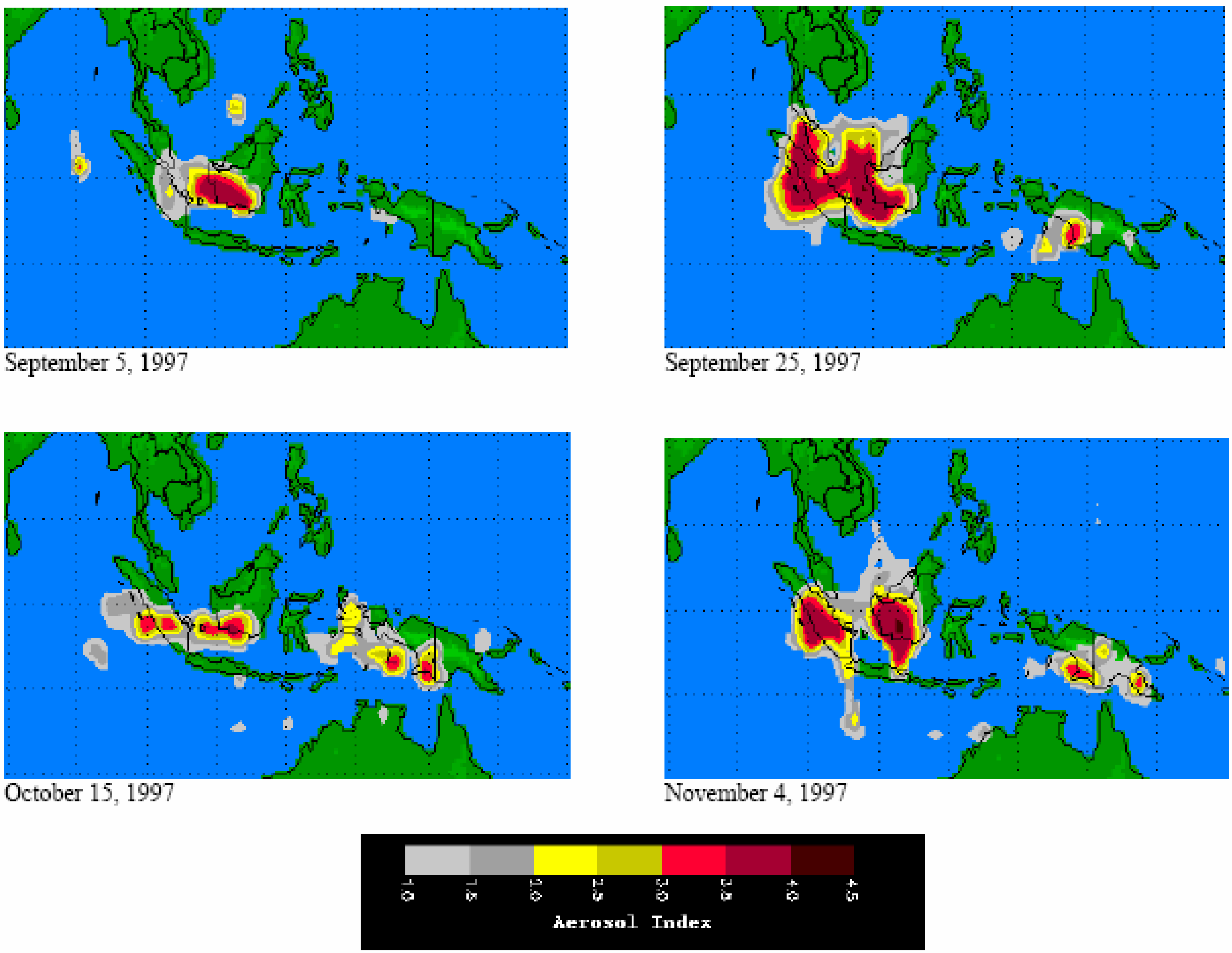
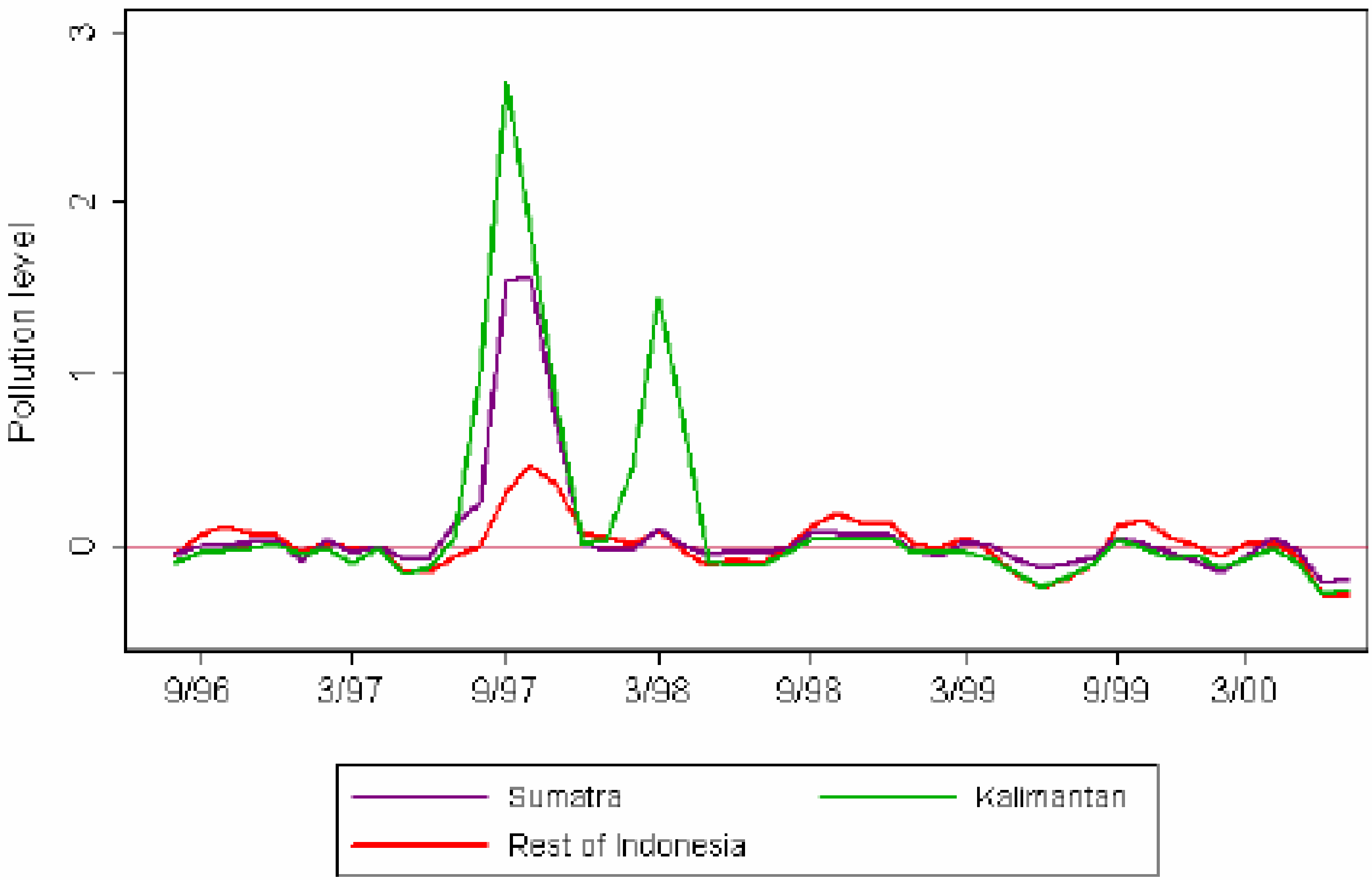


Figure 3: Timing and location of the pollution



# (2) Jayachandran (2006)

- There are no reliable mortality records in Indonesia, but one can use census data (collected in 2000) to capture “missing children”

- Fertility could also be affected by the wildfires, but this is less of a concern if we focus on women *already pregnant* at the start of the unusual weather in mid-1997

# (2) Jayachandran (2006)

- There are no reliable mortality records in Indonesia, but one can use census data (collected in 2000) to capture “missing children”

- Fertility could also be affected by the wildfires, but this is less of a concern if we focus on women *already pregnant* at the start of the unusual weather in mid-1997

- Jayachandran estimates the impact of being *in utero* versus newly born at the time of the largest wildfires (September to November 1997). The question of which period in child development is most influential is of general interest

Thus, the approach I take is to infer fetal and infant mortality by measuring "missing children."[9] The outcome measure is the cohort size for a subdistrict-month calculated from the complete 2000 Census of Population for Indonesia. The estimating equation is

$$\begin{aligned} ln(CohortSize)_{jt} =& \beta_1 Smoke_{jt} + \beta_2 PrenatalSmoke_{jt} + \\ & \beta_3 PostnatalSmoke_{jt} + \delta_t + \alpha_j + \varepsilon_{jt}. \end{aligned} \tag{3.2}$$

The dependent variable, $ln(CohortSize)_{jt}$, is the natural logarithm of the number of people born in month $t$ who are alive and residing in subdistrict $j$ at the time of the 2000 Census. $Smoke_{jt}$ is the pollution level in the month of birth, and the variables $PrenatalSmoke_{jt}$ and $PostnatalSmoke_{jt}$ are included to explore the different timing of exposure, as discussed below. To obtain parameters that represent the average effect for Indonesia, each observation is weighted by the subdistrict's population (the number of people enumerated in the Census who were born in the year prior to the sample period).

**Table 2**
**Relationship Between Air Pollution and Cohort Size**

Dependent variable: Log cohort size

| | Statistic used for smoke measures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Median | Median | Mean | % high-smoke days | Median | Mean | % high-smoke days |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Smoke | -.0005 | | -.001 | -.010 | .001 | .018 | .035 |
| | (.006) | | (.007) | (.020) | (.009) | (.014) | (.036) |
| Prenatal Smoke ($Smoke_{t-1,2,3}$) | -.035 *** | -.032 *** | -.032 ** | -.085 ** | | | |
| | (.012) | (.011) | (.013) | (.033) | | | |
| Postnatal Smoke ($Smoke_{t+1,2,3}$) | -.014 | | -.016 * | -.042 * | | | |
| | (.009) | | (.010) | (.025) | | | |
| $Smoke_{t-1}$ | | | | | -.010 | -.028 * | -.069 * |
| | | | | | (.009) | (.016) | (.040) |
| $Smoke_{t-2}$ | | | | | -.023 *** | -.006 | -.035 |
| | | | | | (.008) | (.013) | (.038) |
| $Smoke_{t-3}$ | | | | | -.003 | -.005 | .005 |
| | | | | | (.013) | (.015) | (.030) |
| $Smoke_{t+1}$ | | | | | -.010 | -.019 | -.030 |
| | | | | | (.009) | (.014) | (.031) |
| $Smoke_{t+2}$ | | | | | -.005 | -.003 | -.034 |
| | | | | | (.008) | (.014) | (.034) |
| $Smoke_{t+3}$ | | | | | .001 | -.001 | .010 |
| | | | | | (.009) | (.012) | (.031) |
| Observations | 67454 | 67454 | 67454 | 67454 | 67454 | 67454 | 67454 |
| Subdistrict and month FEs? | Y | Y | Y | Y | Y | Y | Y |

# (2) Jayachandran (2006)

- One concern is endogenous migration: she captures people where they live in 2000, but households with children could have fled from high smoke areas during or after the wildfires

## Table 3
## Distinguishing between Mortality and Migration

Dependent variable: Log cohort size

| | District of residence versus birthplace versus mother's 1995 residence | | |
|---|---|---|---|
| | Residence | Birthplace | Mother's 1995 residence |
| | (1) | (2) | (3) |
| Smoke | -.002 | .002 | .002 |
| | (.006) | (.006) | (.006) |
| Prenatal Smoke | -.035 *** | -.037 *** | -.038 *** |
| | (.012) | (.012) | (.012) |
| Postnatal Smoke | -.013 | -.015 | -.016 |
| | (.010) | (.010) | (.010) |
| Observations | 5829 | 5829 | 5829 |
| Fixed effects | month, district | month, district | month, district |

# (2) Jayachandran (2006)

- One concern is endogenous migration: she captures people where they live in 2000, but households with children could have fled from high smoke areas during or after the wildfires

- Households in poor areas are significantly more negatively affected than others by the wildfires: air pollution seems to have a very “regressive” impact

**Table 5**

**Effects by Gender and Income**

Dependent variable: Log cohort size

| | By gender | By income (log consumption) of the district | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | <------------------- one regression ----------------------> | | | |
| | | | | | Top quartile | 3rd quartile | 2nd quartile | Bottom quart. |
| | (1) | (2) | (3) | (4) | (5) | | | |
| Smoke | -.008 | -.060 *** | -.024 | -.013 | -.004 | -.011 | -.028 | .002 |
| | (.007) | (.021) | (.016) | (.017) | (.009) | (.010) | (.024) | (.045) |
| Prenatal Smoke | -.030 ** | -.158 *** | -.129 *** | -.090 *** | -.058 *** | -.076 *** | -.094 ** | -.121 ** |
| | (.012) | (.037) | (.028) | (.015) | (.018) | (.017) | (.047) | (.061) |
| Postnatal Smoke | -.019 * | -.158 *** | -.047 * | -.035 ** | -.025 | -.040 *** | -.046 | .009 |
| | (.010) | (.027) | (.024) | (.019) | (.016) | (.014) | (.032) | (.052) |
| Male | .014 *** | | | | | | | |
| | (.003) | | | | | | | |
| Smoke * Male | .016 *** | | | | | | | |
| | (.005) | | | | | | | |
| Prenatal Smoke * Male | -.009 | | | | | | | |
| | (.007) | | | | | | | |
| Postnatal Smoke * Male | .010 | | | | | | | |
| | (.006) | | | | | | | |
| Smoke * High Consum. | | .066 *** | .017 | | | | | |
| | | (.021) | (.014) | | | | | |
| Prenatal Smoke * High Consum. | | .127 *** | .072 *** | | | | | |
| | | (.038) | (.027) | | | | | |
| Postnatal Smoke * High Consum. | | .161 *** | .017 | | | | | |
| | | (.026) | (.014) | | | | | |
| Observations | 134734 | 63158 | 63158 | 63158 | <------------------ 63158 ----------------> | | | |
| Fixed effects included | subdistrict, month | subdistrict, month | subdistrict, month * high cons. | subdistrict, month * high cons. | subdistrict, month*quartile of log consumption | | | |

## Table 6

## Effects By Urbanization, Wood Fuel Use, and Health Care Sector

Dependent variable: Log cohort size

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Prenatal Smoke | -.121 *** | .015 | -.115 *** | -.113 *** | -.007 |
| | (.028) | (.032) | (.027) | (.028) | (.025) |
| Prenatal Smoke * Urbanization | -.013 | | | | |
| | (.013) | | | | |
| Prenatal Smoke * Wood Fuel Use | | -.155 *** | | | -.120 *** |
| | | (.036) | | | (.026) |
| Prenatal Smoke * Maternity Clinic | | | .030 *** | | .011 ** |
| | | | (.009) | | (.005) |
| Prenatal Smoke * Doctors | | | | .048 *** | .016 |
| | | | | (.015) | (.013) |
| Prenatal Smoke * High Consum. | .071 *** | .048 * | .058 ** | .052 ** | .044 * |
| | (.027) | (.025) | (.025) | (.025) | (.025) |
| Observations | 63158 | 63158 | 63158 | 63158 | 63158 |
| Subdistrict and month FEs? | Y | Y | Y | Y | Y |

# (2) Jayachandran (2006)

- One concern is endogenous migration: she captures people where they live in 2000, but households with children could have fled from high smoke areas during or after the wildfires

- Households in poor areas are significantly more negatively affected than others by the wildfires: air pollution seems to have a very “regressive” impact

- 16,000 excess infant/fetal deaths. Valuing a life at US$1 million leads to a valuation of US$16 billion (ignoring costs for survivors). Total timber and palm oil industry revenues per year was only US$7 billion!

# (3) Foster and Rosenzweig (2003)

- Does economic growth lead to deforestation? The cross-country evidence is unclear

- Argue that local economic growth, by boosting the demand for forest products / the price of fuel, increases forest cover rather than decreasing it (supply response)

  -- Alternative stories that they reject: richer people choose to consume more “nature” amenities; or practice more resource conservation

- Evidence from the U.S. historically and India recently are consistent with the view that economic growth could promote afforestation (growth of forests)

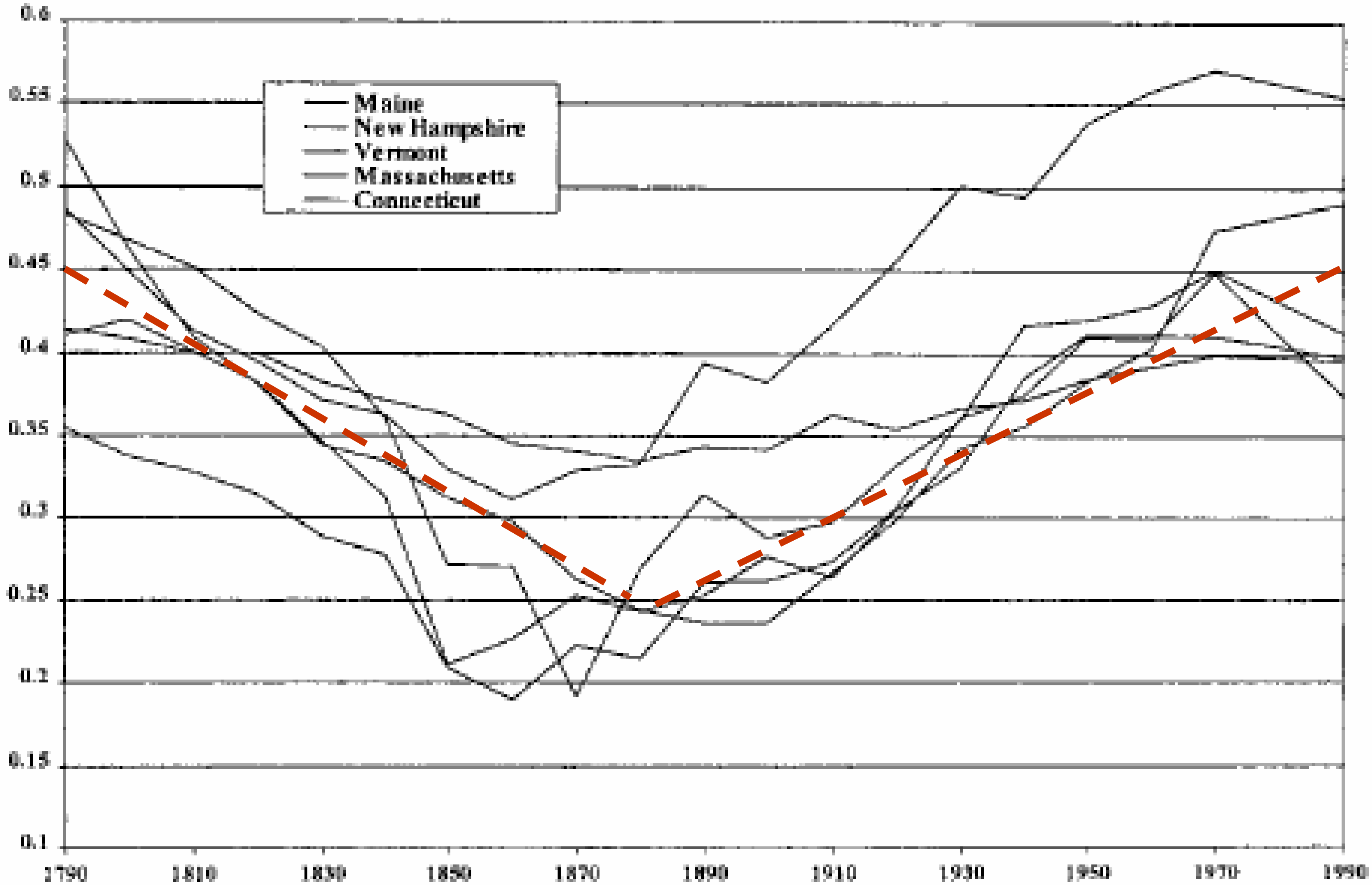



FIGURE I
Proportion of Total Land Forested, by State, U. S. New England States
1790–1990

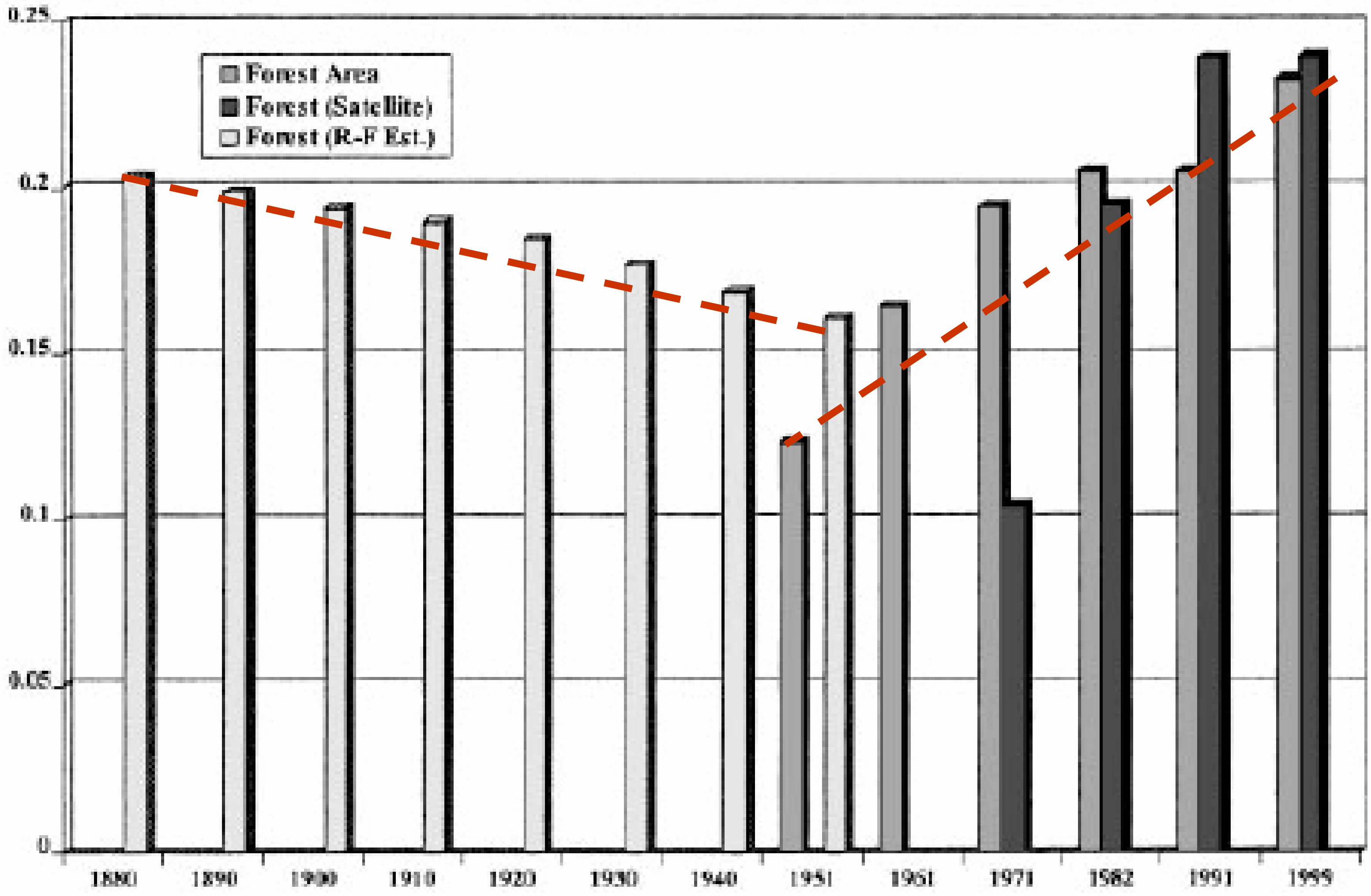



FIGURE II

Proportion of Total Land Area Classified as Forest (Government Statistics) and Proportion of Land Forested (Richards and Flint Estimates and Satellite Data for Survey Villages), India 1880–1999

One possibility is that income growth leads to a greater demand for environmental amenities and direct efforts to conserve resources such as trees. The recycling of paper in the United States and Europe is motivated in part by tree "conservation." For example, one U. S. environmental organization promoting recycling provides the estimate that there will be a four-pound reduction in carbon dioxide for every pound of paper recycled [Environmental Defense 2001]. This implies that saving paper increases trees. An alternative view is that economic growth leads to an increase in the demand for forest products and that, like other renewable resources, this leads to a shift in land use toward trees. If this is the case, then efforts to conserve paper would curtail forest growth not promote it. Thus, an improved understanding of the linkages between economic growth and forest change has important implications for environmental policies in all countries.

# (3) Foster and Rosenzweig (2003)

- The relationship between local demand for forest products and the local supply (extent of forest) should be stronger in closed economies than open economies

  -- E.g., imports were <1% of total domestic wood consumption in India in the 1980s

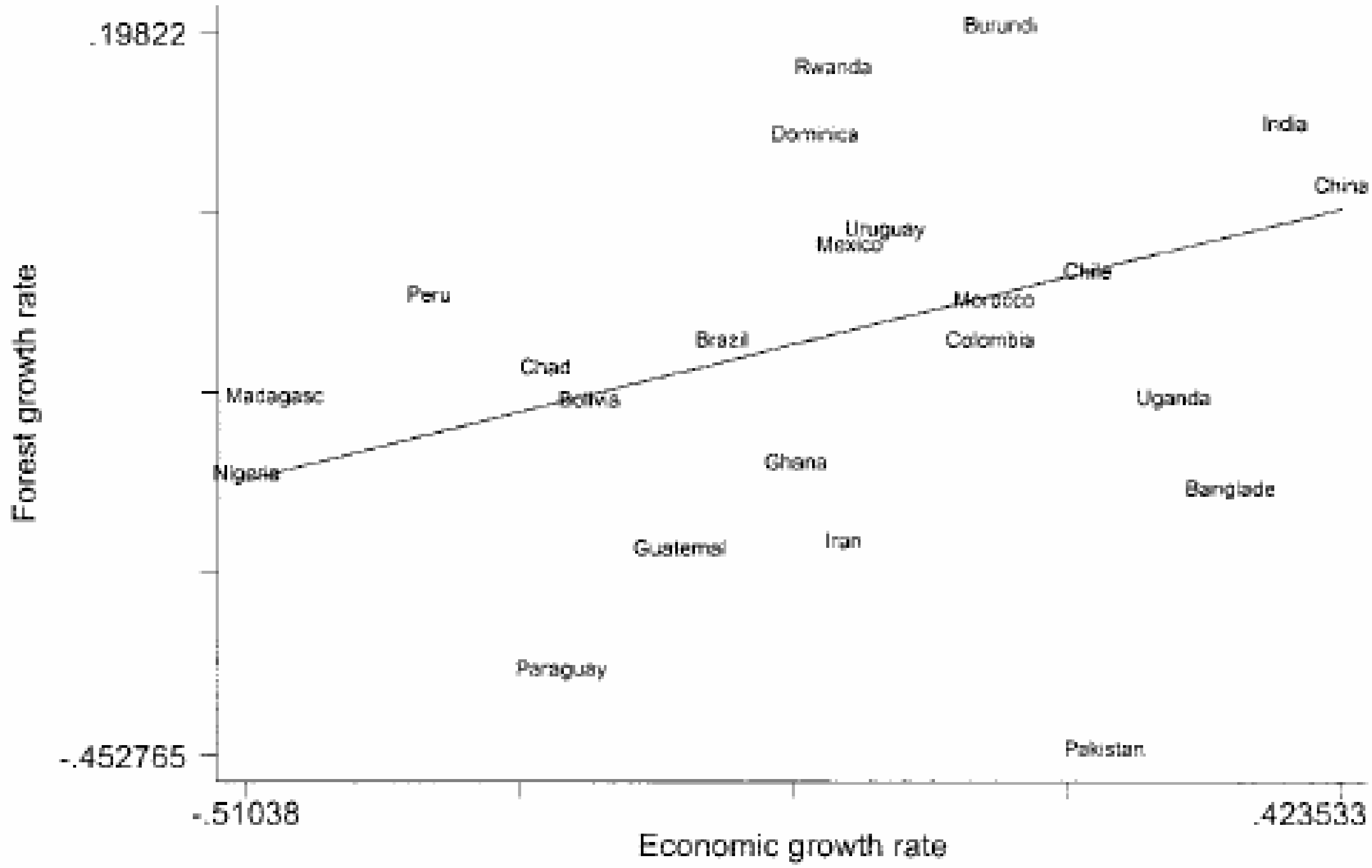



FIGURE VI
Economic Growth and Forest Growth, 1980–1995: Closed Economies

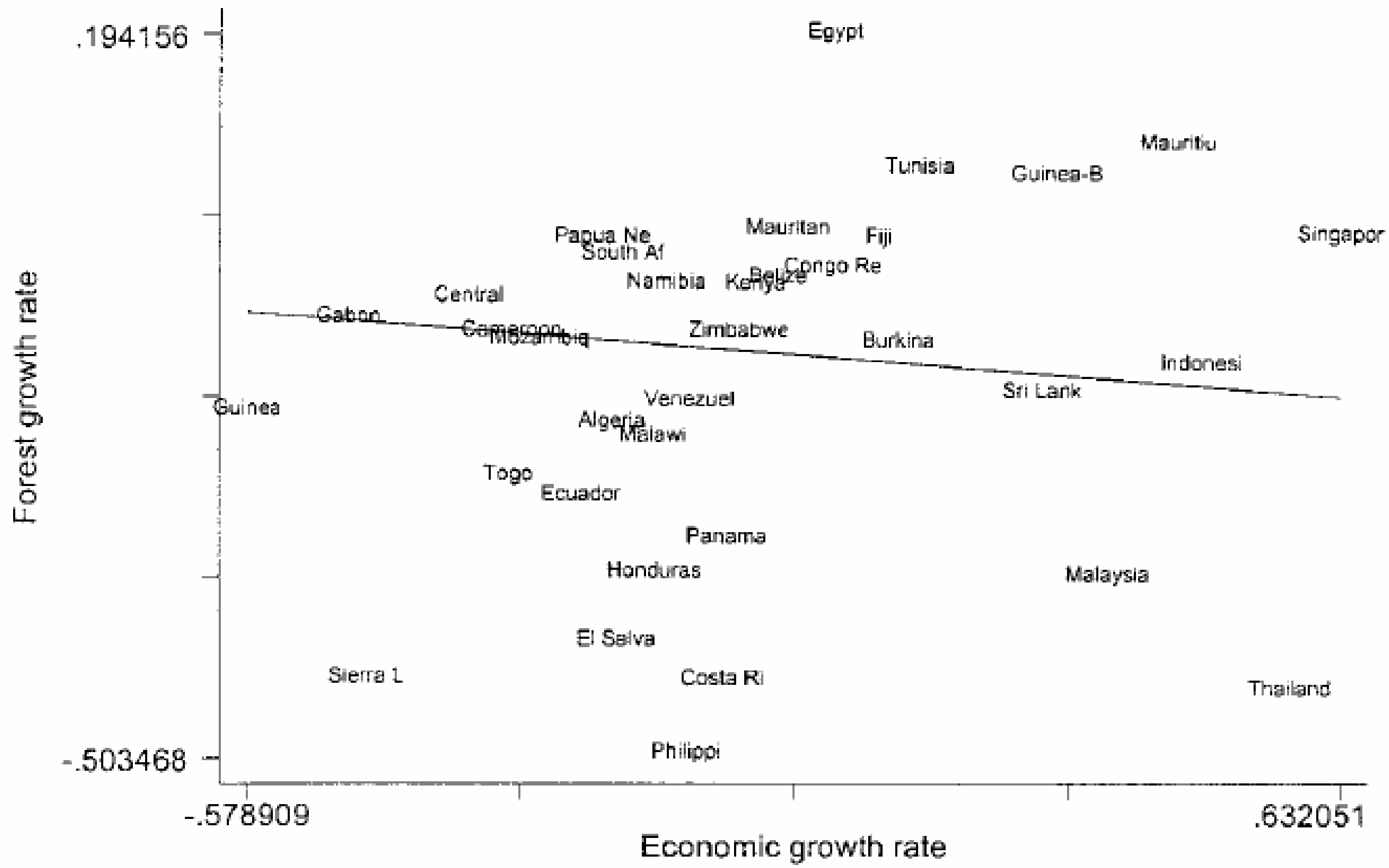



FIGURE V
Economic Growth and Forest Growth, 1980–1995: Open Economies

# (3) Foster and Rosenzweig (2003)

- The relationship between local demand for forest products and the local supply (extent of forest) should be stronger in closed economies than open economies

- They then treat Indian villages as closed economies with immobile labor (but within-India trade in finished forest products), to study the impact of local changes in agricultural productivity (the Green Revolution), wages, and population on local forests

# (3) Foster and Rosenzweig (2003)

- Verbal model: they assume HH utility increases in forest products, but in not forest cover *per se*
- Assume well defined property rights (private or government management)
- General equilibrium: changes in population and agricultural technology affect the opportunity costs of land and labor (forest inputs) and thus forest “supply”, though few truly general results
- If forest products are normal goods, local forest cover should rise with local income

# (3) Foster and Rosenzweig (2003)

- Findings from roughly 250 villages 1971-1999: increased crop productivity reduces forest cover (as land shifts towards a higher value use); no link with wages; population growth *boosts* cover

- Issues in the analysis:

  -- Use normalized differentiated vegetation index (NDVI) from satellite data, where NDVI>0.2 denotes forests. However, distinguishing forest cover and agricultural crops using NDVI is difficult (as they acknowledge)

  -- Missing data, attrition, different samples across specs

  -- Years of satellite data and surveys do not line up

  -- Local fuel prices not unobserved, unfortunately

# (3) Foster and Rosenzweig (2003)

- Issues in the analysis:

  -- Very weak IV's for agricultural productivity (Table 2), and thus imprecise FE-IV results for input costs (Table 3)

TABLE II

Predicting Equations for Log of HYV Yield: OLS and Village Fixed-Effects (FE) Estimates[a]

| Variable | OLS | FE |
|---|---|---|
| Year = 1982 | .834 | 1.02 |
| | (3.88)[b] | (7.74) |
| Year = 1999 | 1.26 | 1.55 |
| | (5.83) | (10.1) |
| Proportion village area under wheat in 1971 | 1.49 | — |
| | (3.77) | |
| Wheat * year = 1982 | −.929 | −1.12 |
| | (1.88) | (2.58) |
| Wheat * year = 1999 | −.756 | −.894 |
| | (1.51) | (2.13) |
| Proportion village area under rice in 1971 | .566 | — |
| | (1.45) | |
| Rice * year = 1982 | −.158 | −.404 |
| | (0.41) | (1.93) |
| Rice * year = 1999 | −.269 | .518 |
| | (0.76) | (2.80) |
| Village in IADP | .0690 | — |
| | (0.31) | |
| IADP * year = 1982 | −.108 | −.0204 |
| | (0.42) | (0.14) |
| IADP * year = 1999 | −.187 | −.163 |
| | (0.77) | (1.24) |
| Village electrified | .391 | .244 |
| | (4.08) | (2.55) |
| Good (*pucca*) access road in village | .0278 | −.103 |
| | (0.36) | (1.13) |
| Log household size | −.151 | −.390 |
| | (1.13) | (3.36) |
| Log population | .0642 | .0845 |
| | (1.60) | (1.35) |
| Rainfall ($\times 10^{-3}$) | −.0889 | .0084 |
| | (0.93) | (0.08) |
| *Panchayat*/common land in village | −.0778 | — |
| | (1.03) | |
| Constant | 4.87 | — |
| | (16.1) | |
| *F*-statistic, all variables (d.f., d.f.) | 18.0 | 4.26 |
| | (20,252) | (268,434) |
| *F*-statistic, instruments (d.f., d.f.) | 3.04 | 2.63 |
| | (9252) | (6434) |
| Number of observations | 703 | 703 |

# (3) Foster and Rosenzweig (2003)

- Issues in the analysis:

  -- Very weak IV's for agricultural productivity (Table 2), and thus imprecise FE-IV results for input costs (Table 3)

  -- IV's in the main forest cover results (Table 4) include crop composition and participation in a government agricultural extension program * time FE, as well as local infrastructure (roads, electrification) * time FE. Do the latter violate the exclusion restriction? I.e., reduce the cost of transporting forest products to other markets thus raising its price?

  -- Imprecise IV estimates mean we cannot say much about local wage or income "impacts" with much confidence. No evidence for paper's main punchline?

TABLE IV

EFFECTS OF AGRICULTURAL PRODUCTIVITY, WAGE RATES, INCOME, AND POPULATION ON FORESTED AREA (NDP), FOREST BIOMASS (NDT), AND (LOG) PROPORTION LAND AREA CULTIVATED: CROSS-SECTION OLS, VILLAGE FIXED EFFECTS, AND FE-IV ESTIMATES[a]

| Variable | NDP | | | NDT | | | Log proportion land cultivated | | |
|---|---|---|---|---|---|---|---|---|---|
| Estimation procedure | OLS | FE | FE-IV | OLS | FE | FE-IV | OLS | FE | FE-IV |
| Log HYV productivity (rupees)[b] | .0262 | −.0490 | −.264 | .00780 | −.0170 | −.110 | .145 | .107 | .566 |
| | (0.87)[c] | (2.32) | (2.72) | (0.66)[c] | (2.36) | (3.09) | (1.04) | (2.02) | (1.68) |
| Log of wage rate[b] | .0308 | −.0722 | −.268 | .0154 | −.0242 | −.0823 | −.558 | −.320 | −1.17 |
| | (0.71) | (1.49) | (1.11) | (1.02) | (1.46) | (0.92) | (4.67) | (3.03) | (1.51) |
| Log household income[b] | .0852 | .0493 | .0392 | .0185 | −.00451 | −.0416 | .149 | .0600 | .391 |
| | (1.54) | (1.01) | (0.22) | (1.09) | (0.27) | (0.64) | (0.98) | (0.56) | (0.95) |
| Log household size | −.0671 | −.106 | −.263 | −.0310 | −.0303 | −.0894 | .123 | −.00512 | .0802 |
| | (1.61) | (1.98) | (2.86) | (1.82) | (1.66) | (2.64) | (0.81) | (0.04) | (0.32) |
| Log population | .0778 | .137 | .119 | .0221 | .0359 | .0312 | −.194 | .0112 | .00484 |
| | (5.50) | (5.10) | (3.28) | (5.57) | (3.91) | (2.33) | (2.97) | (0.17) | (0.04) |
| Rainfall (mm $\times 10^{-3}$) | .0534 | .0238 | .0331 | .0250 | .0362 | .0202 | — | — | — |
| Number of obs. | 568 | 568 | 568 | 568 | 568 | 568 | 672 | 672 | 672 |

a. All specifications include year-effects dummy variables and dummy variables indicating missing values for population and household size.

b. Endogenous variable in columns 4, 7, and 10. Instruments are rice-, wheat-growing regions and IADP interacted with year indicator variables.

c. Absolute value of $t$-ratio in parentheses is corrected for nonindependence of errors within villages.

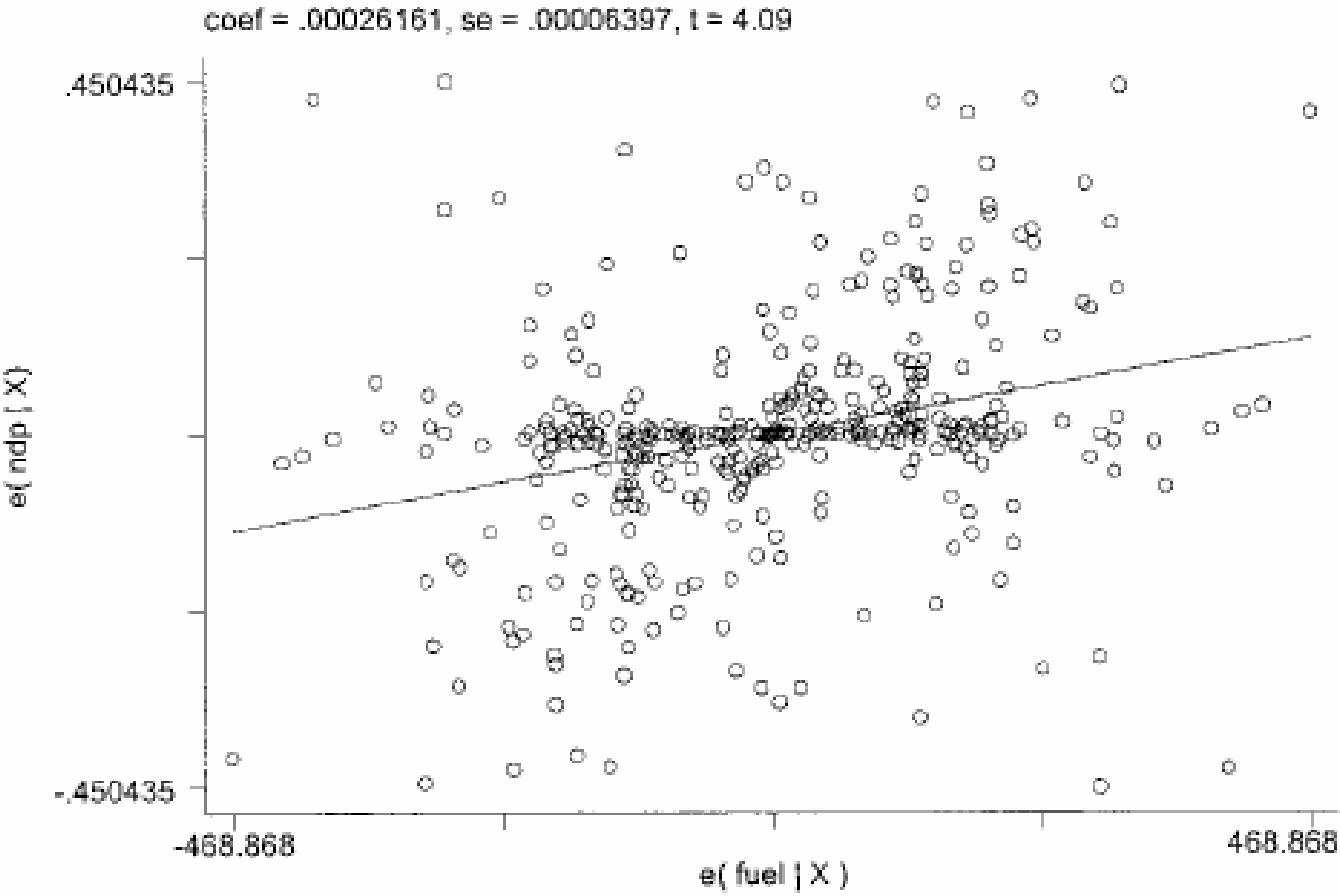



FIGURE VII
Relationship between Change in Fuel Expenditures and Change in NDP, Indian Villages, 1971–1982

# (3) Foster and Rosenzweig (2003)

- Some take-away points:
- The tradability of forest products matters a lot: the link between local demand and local forests (at the village, or even country level) is broken by trade

- Particular forests have intrinsic value (Yosemite, old growth oak or redwood), as could endangered species

- Institutions matter: common pool/overfishing problems could be important in the absence of strong government property rights enforcement (Ostrom 1990)

  -- Growing demand for forest products may not lead to greater supply if government control is weak

Our findings should not be interpreted as meaning that issues of forest management emphasized in the literature are not important. The translation of increased demand for forest products into expanded forests is not automatic, but depends importantly, as expressed by Arrow et al. [1995], on the "context of growth" [p. 521]. In part, this context is itself affected by growth. In India, in particular, the increase in the demand for marketable tree products is in part responsible for the implementation of the Joint Forest Management Program in the 1980s, which provides villagers with a share of the sales proceeds from timber extracted from public forests. Clearly, without appropriate incentives in place, shifts in demand and supply would not be aligned. However, it is possible that without the shift in demand for forest products, effective policy reforms expanding forests may not have been feasible. Finally, future demand-led forest growth clearly will affect the composition of forests and their distribution worldwide. To the extent that tree species diversity, "natural" forests, or specific locations of forests are valued, and not just the aggregate world quantity of trees, restrictions on forest exploitation in particular contexts may be warranted.[18]

# (4) Kremer et al 2009

- Property rights institutions are thought to be critical to economic performance

- Social norms and legal institutions often establish communal property rights to natural resources

  -- Islamic law prohibits water sale; land in African villages

  -- Goldstein and Udry (2005) argue that communal norms distort land use decisions in Ghana

- Kremer et al (2009) focus: water in Kenya is a communal resource according to both traditional norms and law

  -- What impact of alternative norms – private property rights, or government provision – on social welfare?

# The Rural Water Project (RWP)

- Randomized evaluation of alternative water interventions in rural western Kenya
  - This paper studies source water quality improvement through *spring protection* in 184 rural communities

Other projects:

- Point-of-use water treatment (chlorination)
- Increased water quantity
- Alternative water maintenance policies

# Findings and contributions

1) First randomized evaluation of source water improvement
   -- Source water contamination falls 66%, home water 24%
   -- Child diarrhea falls one quarter (4.7 percentage points)

2) Revealed preference estimates of the value of clean water and child health, using a travel cost approach
   -- Stated preference valuation three times higher

3) Novel – and very low – estimates of the value of a statistical life in rural Africa, < US$500

4) Simulate welfare under alternative property rights norms
   -- Private property rights do poorly, large static distortions with little additional investment
   -- A public voucher system boosts social welfare

# The Economics of Rural Water

- There are two million child diarrhea deaths annually

- Millennium Development Goals aim to reduce by half the proportion of people without access to safe water
  -- Piping treated water into homes is the ideal, but is impractical with dispersed rural populations
  -- Most water sector spending today is on communal water supply infrastructure (e.g., wells, springs)

- The debate on source water improvements
  -- Recontamination in transport, storage → point-of-use?
  -- Interactions with hygiene and sanitation
  -- Water quality vs. quantity
  -- Adequate institutions for provision and maintenance

# Project Background

- Child mortality in Kenya is high at 120 per 1000 live births (2005), and even higher in rural areas
  - Diarrheal disease is a leading cause
- Average distance to nearest water source is 10 minutes
  - Roughly two hours of collection time per HH per day
- Multiple local water sources are common:
  - Naturally occurring springs
  - Boreholes / deep wells
  - Shallow wells
  - Streams, ponds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# Spring Protection Project Component

- 200 natural springs identified in 2004
  - Springs stratified by location and baseline water contamination, divided into four treatment groups
  - 16 springs later dropped as unsuitable for protection (e.g., seasonal water only)
  - Order of protection determined randomly

- Across four survey rounds (2004, 2005, 2006, 2007), 184 springs with water and household panel data

- One quarter of baseline sample phased into spring protection in early 2005, one quarter in late 2005

# A travel cost model of water source choice

- A travel cost conditional logit model (McFadden 1974):

$$U_{ijt} = V(W_{ij}) - CD_{ij} + e_{ijt} \qquad (3)$$

-- Distance to source *D*, value of time is *C>0*

-- *V(W)* health impacts of water contamination level *W*

-- Extreme value errors $e_{ijt}$ across multiple choice situations (household i, source j, time t)

- Utility from spring protection per minute of walking time is a revealed preference measure of willingness to pay for cleaner water

- Estimate heterogeneous valuations using mixed logit: random coefficients on spring protection, walking time

Table 6: Discrete choice models (conditional and mixed logit) of water source choice (2007 surveys)

| | Revealed Preference | | | | | Stated Ranking | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Treatment (protected) indicator | 0.51*** | -0.02 | 0.34*** | 0.68*** | | 0.96*** | |
| | (0.04) | (0.08) | (0.08) | (0.09) | | (0.24) | |
| Mixed logit – Mean (normal): | | | | | 2.95*** | | 1.46** |
| | | | | | (0.25) | | (0.60) |
| Mixed logit – Std. dev. (normal): | | | | | 5.73*** | | 1.22 |
| | | | | | (0.33) | | (0.75) |
| ln (source water E. coli MPN) | | -0.14*** | | | | | |
| | | (0.01) | | | | | |
| Water quality at source perceived to be above average | | 1.14*** | | | | | |
| | | (0.07) | | | | | |
| Distance to water source (minutes walking) | -0.055*** | -0.059*** | -0.031*** | -0.053*** | | -0.033*** | |
| | (0.001) | (0.002) | (0.003) | (0.002) | | (0.010) | |
| Mixed logit – Mean (restricted triangular): | | | | | -0.21*** | | -0.03*** |
| | | | | | (0.01) | | (0.01) |
| Mixed logit – Std. dev (restricted triangular) | | | | | 0.09 | | 0.001 |
| Source type: Borehole/piped | -0.08 | | -0.05 | -0.13* | -1.02*** | 0.07 | 0.04 |
| | (0.05) | | (0.07) | (0.08) | (0.14) | (0.25) | (0.27) |
| Source type: Well | -0.28*** | | -0.35*** | -0.31*** | -1.87*** | -0.43* | -0.47* |
| | (0.05) | | (0.07) | (0.07) | (0.13) | (0.24) | (0.25) |
| Source type: Stream/river | -0.77*** | | -0.71*** | -0.63*** | -1.46*** | -2.19*** | -2.25*** |
| | (0.06) | | (0.09) | (0.09) | (0.15) | (0.52) | (0.53) |
| Source type: Lake/pond | -0.20 | | -0.20 | -0.18 | -0.32 | -2.82 | -2.85 |
| | (0.14) | | (0.20) | (0.19) | (0.35) | (1.86) | (1.87) |
| Log likelihood at convergence | -11743 | -2626 | -5416 | -5392 | -3980 | -363 | -363 |
| Number of observations | 53427 | 29068 | 50988 | 50024 | 53427 | 2114 | 2114 |

# Alternative property rights to water

- Current Kenyan law and custom allows free community access to spring water sources for “domestic use”

  -- Status quo: few springs are currently protected

- Potential upside to private property rights: investment incentives could overcome collective action problems

  -- Downsides: Water prices above MC (=0) generate static distortions (in source choice, distance walked); distributional consequences (losses for consumers?)

- What is social welfare under alternative institutions?

  (i) Social planner

  (ii) Private property rights (spring owners can charge)

  (iii) Government investment

  (iv) Public vouchers

# Planner's problem: isolated springs

- Simplest case first: under the assumptions that

  -- 31 households / spring, and protection lasts 15 years

  -- Annual protected spring maintenance is $35

- Discounted cost of construction, maintenance: $1405

  -- With tax distortions ($\approx$0.3 of revenue) = $1827
- Discounted benefit of spring protection: $1110

- This low return could explain low levels of protection

  -- It appears socially optimal to only protect springs with many users (e.g., densely populated areas): with 46 household users per spring, returns become positive

# Simulating alternative property rights

- The estimated distribution of valuations for clean water provides the water "demand side"

  -- Preferences (from mixed logit) are $\theta_{ijg} = \{\beta_{ijg}, \gamma_{ijg}, \delta_{ijg}\}$, where $\beta$ is the utility value of spring protection for household i at spring j in group g; $\gamma$ is the disutility of a minute of walking time; and $\delta$ is household value of time

- Assume the social planner and local spring owners know $\theta_{ijg}$ for all households, but government only knows $F(\theta_{ijg})$

  -- Assume government revenue generation leads to deadweight loss

  -- Consider groups of up to four neighboring springs (within 1 km) that can compete with each other

# Simulating alternative property rights

- Consider the following game:

  -- t=0: The property rights regime is chosen

  -- t=1: spring owner / planner decide on protection

  -- t=2: spring owner / planner optimally set water prices

  -- t=3: Households make water consumption choices

- Solve for the Nash equilibrium in price and protection using a combination of grid search and other numerical (Nelder-Mead simplex) methods

  -- No collusion allowed among spring owners

# Social planner solution

The social planner's decision problem can be represented as follows, where $W^S$ denotes social welfare:

$$(6) \qquad \underset{\{protect_g\}_g}{Max}\ W^S = \sum_{g=1}^{G}\left\{\sum_{j=1}^{J}\sum_{i-1}^{I} V_{ijg}(protect_g \mid \theta_{ijg}) - C * \sum_{j=1}^{J} protect_{jg}\right\}$$

where $V_{ijg}(protect_g \mid \theta_{ijg})$ denotes household utility given that the planner is fully informed about true household preference parameters, $\theta_{ijg}$.

- The social planner optimally protects 27.5% of sample springs, with a social welfare gain of US$340.80 per spring community (each with roughly 200 people)
- Under stated preference valuations, the social planner would protect over 97% of springs

# “Full” private property rights norms

$$(7) \qquad \underset{protect_{jg}}{Max}\ \pi_{jg} = p^*_{jg} \sum_{j'=1}^{J'} \sum_{i=1}^{I} \{T_{ijj'g}(protect_{jg}, protect^*_{-jg}, p^*_g) \mid \theta_{ijg}\} - C * protect_{jg}$$

The double summation refers to all households in the spring group that $j$ belongs to, and $T_{ijj'g}$ is the number of trips the household makes to spring $j$ given the equilibrium protection status and price decisions of all springs in the group. This is solved subject to optimal non-cooperative price setting: $p^*_{jg} = \underset{p_{jg}}{\arg\max}\, \pi_{jg}(protect_{jg}, protect^*_{-jg}, p^*_{-jg})$.

- Only 5.4% of springs are protected, with social welfare losses of US$77.53 per spring community
- Large spring owner profits, little protection but high prices; 97% of households worse off than the status quo
- Walking times, use of bad sources (i.e. ponds) rise

Table 8: Property Rights Institutions: Counterfactual Policy Simulations

| | Proportion of springs protected | Average price per water trip, conditional on price>0 (USD) | NPV profits, per land owner (USD) | NPV household welfare, per spring (USD) | Proportion households worse off than status quo | Social welfare, per spring (USD) |
|---|---|---|---|---|---|---|
| (1) Status quo | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Social planner | 0.275 | 0.0 | 0.0 | 700.0 | 0.198 | 340.8 |
| (3) "Full" private property rights | 0.054 | 0.0028 | 441 | -518 | 0.972 | -77.5 |
| Springs social planner does not protect | 0.008 | 0.0026 | 306 | -411 | 0.978 | -105.0 |
| Springs social planner protects | 0.174 | 0.0033 | 796 | -802 | 0.960 | -5.2 |
| (4) "Conditional" private property rights | 0.108 | 0.0006 | 90 | -135 | 0.187 | -44.9 |
| Springs social planner does not protect | 0.041 | 0.0002 | 24 | -103 | 0.134 | -78.9 |
| Springs social planner protects | 0.283 | 0.0017 | 262 | -217 | 0.287 | 45.0 |
| (5) "Open access" private property rights | 0.024 | 0.0085 | 16 | 28 | 0.000 | 43.4 |
| Springs social planner does not protect | 0.000 | 0.0000 | 0 | 18 | 0.000 | 18.2 |
| Springs social planner protects | 0.087 | 0.0085 | 57 | 52 | 0.000 | 109.8 |
| (6) Public investment (with 30% tax deadweight loss) | 0.243 | 0.0000 | 0 | 528 | 0.196 | 115.9 |
| Springs social planner does not protect | 0.122 | 0.0000 | 0 | 366 | 0.136 | 158.9 |
| Springs social planner protects | 0.560 | 0.0000 | 0 | 953 | 0.329 | 2.6 |
| (7) Voucher (with 30% tax deadweight loss) | 0.115 | 0.0 | 38 | 319 | 0.101 | 112.9 |
| Springs social planner does not protect | 0.051 | 0.0 | 19 | 233 | 0.082 | 140.6 |
| Springs social planner protects | 0.283 | 0.0 | 90 | 546 | 0.138 | 40.1 |

# “Conditional” private property rights

- “Conditional” private property rights: positive prices can only be charged if the spring is protected

  -- More spring owners invest in protection (10.8%), and average prices fall, reducing household losses

  -- Social welfare still falls substantially

- “Open access” privatization also requires spring owners to always retain access to unprotected spring water

  -- A Pareto improvement relative to the status quo, small positive social welfare gains ($43.40/spring)

  -- An attractive institution in settings where government capacity is limited; easy to monitor compliance

# Forms of government provision

- Public investment leads to large welfare gains, even with 30% deadweight loss

  -- Too optimistic in settings where public resources are often misused (e.g., Reinikka and Svensson 2004)?

- A voucher system also yields large welfare gains

  -- The government sets a single voucher price (paid to spring owners for each collection trip) knowing $F(\theta_{ijg})$

  -- Private investment incentives, no static distortions

  -- Can attain higher protection levels by raising the voucher price, if households undervalue clean water (due to disease externalities, lack of knowledge, within household agency problems, etc.)

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# Discussion and conclusion

- Spring protection improved water and child health

  -- But households value spring protection at only 18.5 work days ($1.76) per year, low valuation on child health

  -- Stated and revealed preference values diverge sharply

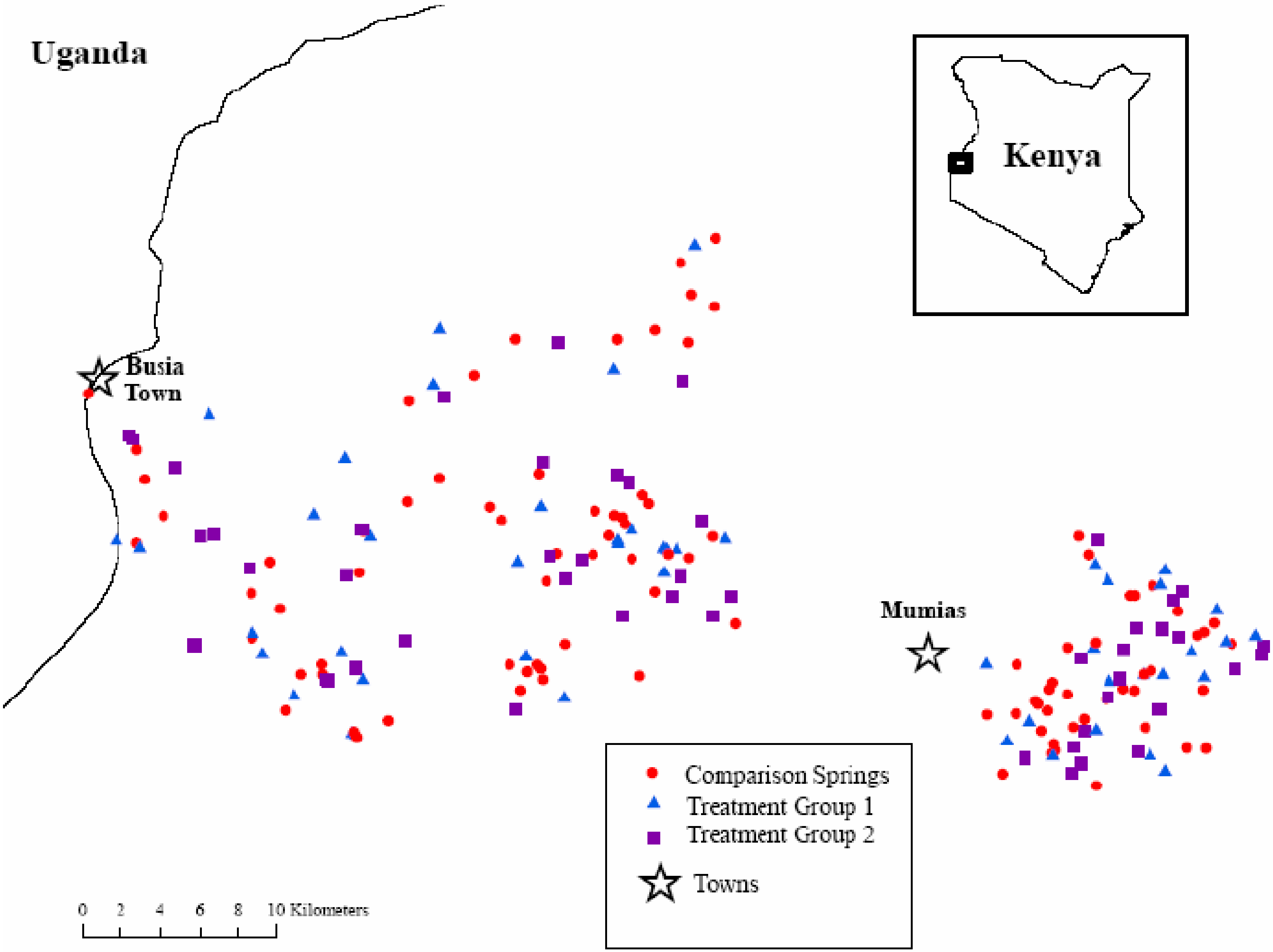
- Property rights norms and institutions regarding natural resources have a major impact on social welfare

  -- Full private rights unattractive here, but “open access” private property rights, vouchers boost social welfare

  -- Islamic law (*hadith*) evolved to grant those investing in water infrastructure the right to sell water, while maintaining open access to unimproved sources

- The transition from one set of norms/institutions to another remains a major issue in economic development

Figure 1: Rural Water Project (RWP) study region and sample springs



# Whiteboard #1

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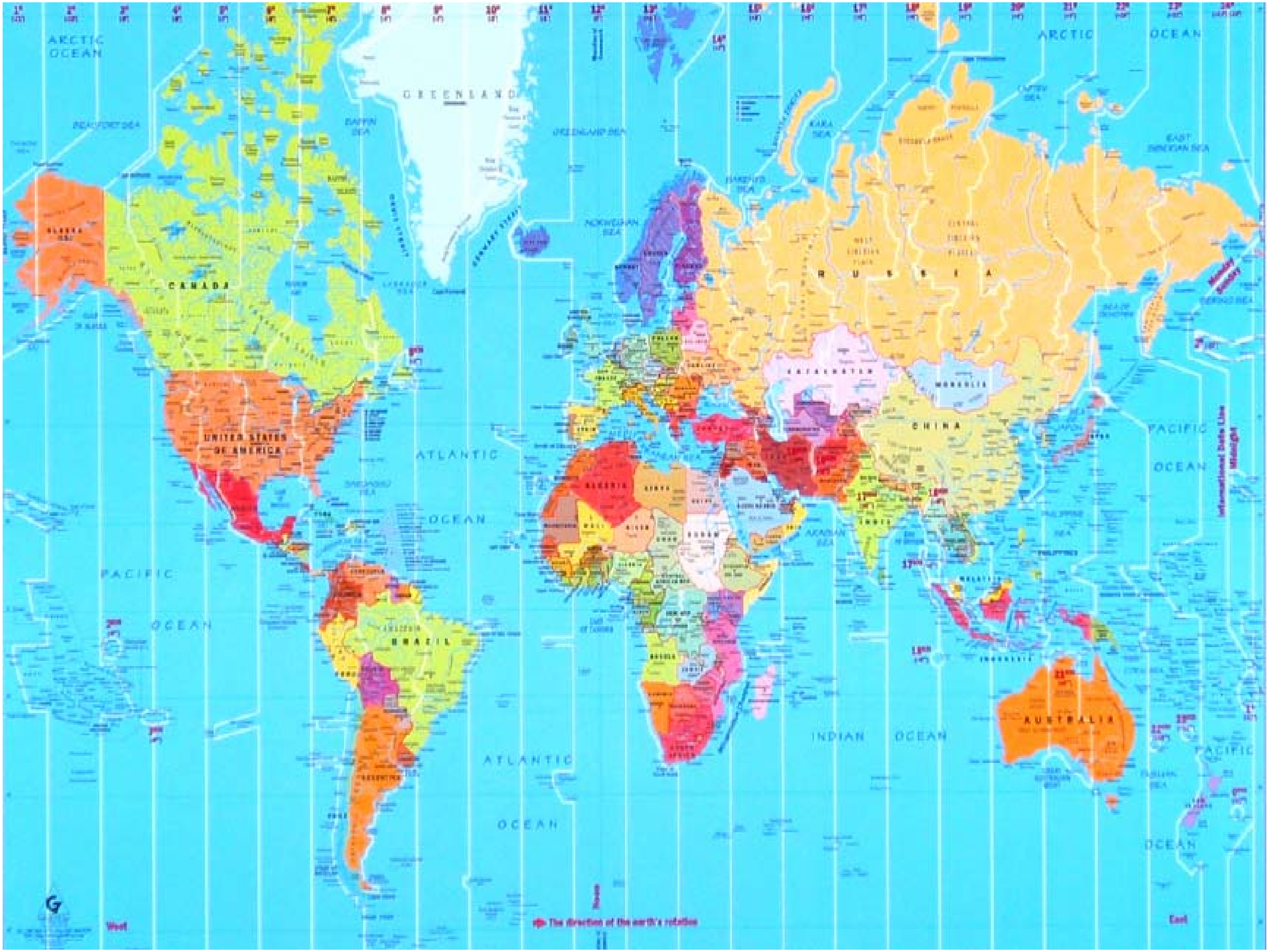

ARCTIC OCEAN
GREENLAND
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UNITED STATES OF AMERICA
ATLANTIC OCEAN
PACIFIC OCEAN
BRAZIL
RUSSIA
CHINA
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INDIA
ALGERIA
INDIAN OCEAN
INDONESIA
AUSTRALIA
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
International Date Line Midnight
West
The direction of the earth's rotation
East