Weather, climate and the economy

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Climate matters

• Climate matters to the economy
• If not, climate change would not matter
• This is not the same as climate determinism
  • 管仲 (Guan Zhong), Hippocrates, Aristotle, Ibn Khaldun, Huntington, Diamond all argue that geography is destiny, that the character of a people, and hence its success is determined solely by the prevailing environmental conditions
Climate matters

• Mainstream economists are institutional determinists
  • The only thing that matters to humans are other humans (Easterly & Levine JME 2003; Rodrik, Subramanian & Trebbi JEG 2004)
  • Climate mattered in shaping institutions, but is no longer relevant now (Acemoglu, Johnson & Robinson AER 2001; Alsan AER 2015)
• If true, climate change is irrelevant in the long run, perhaps matters in transition
Climate matters

- Climate matters for agriculture, for energy demand, for tourism, for health, for labour productivity
- Climate explains, in part, the income distribution within countries (Nordhaus *PNAS* 2006; Henderson, Squires, Storeygard & Weil *QJE* 2018)

- Identification is problematic
  - Climate varies slowly over time, many confounders
  - Climate varies strongly over space, many confounders
Weather and economic output


- Weather is random from an economic perspective, and claims of causality are readily made

- Weather affects many economic activities that in turn affect one another
Weather and economic growth

• Weather shocks affect growth
  • More so in poor countries (Dell, Jones & Olken AER 2009, AEJ Macro 2012; Letta & Tol ERE 2018)
  • More so in hot countries (Burke, Hsiang & Miguel Nature 2015; Burke, Davis & Diffenbaugh Nature 2018)

• Cross-validation somewhat favours specifications in which weather affects the level of economic activity rather than its growth rate (Newell, Prest & Sexton RFF 2018)
Weather and economic output

• Problematic extrapolation from weather to climate (Dell et al. *JEL* 2014)
  • Climate is what you expect, weather is what you get
  • Response to weather shocks is limited: Put up an umbrella, close the flood gates
  • Adaptation to climate is extensive: Buy an umbrella, build flood gates

• Conditions for weather impacts to inform climate impacts are strict (Deryugina & Hsiang *NBER* 2017) or very strict (Lemoine *NBER* 2018)

• There are also papers that apply climate change impact functions to weather shocks (Cai & Lontzek *JPE* 2019; Caleb, Chapman, Stainforth & Watkins *Nat Comm* 2020)
Contribution

• Simultaneously model impacts of *climate* and *weather* on economic activity
• Climate impacts production potential
  • Denmark is good for Holsteiners, bad for rice
  • Thailand is good for rice, bad for Holsteiners
• Weather shocks are lost potential
  • Crop failure
  • Disruptions of production and transport
• Climate in production frontier, weather as a source of inefficiency
• Stochastic Frontier Analysis
Data

- DepVar: Output per worker (Penn World Tables 9.0)
- 1950-2014, 160 countries
- Frontier: Capital per worker (PWT 9.0), 30-year average temperature and rainfall, gridded data (University of Delaware 2014), aggregated using population weights
- Inefficiency: temperature and rainfall anomalies (absolute values of level differences from long-run averages, normalized by dividing by the long-run standard deviation)
Stochastic frontier analysis

• Production efficiency, a frontier that cannot be exceeded but is imperfectly observed
• Deviations from this extreme represent inefficiencies, inframarginal producers that would up their game or go bankrupt later
• Composite error term: two-sided idiosyncratic error plus a one-sided error that represents inefficiency
• Originally developed for cross-sectional data (Aigner, Lovell and Schmidt, 1977; Meeusen & Van den Broeck, 1977)
  • Panel data (Pitt & Lee, 1981; Battese & Coelli, 1988)
  • Time-varying inefficiency (Kumbhakar, 1990; Battese & Coelli, 1992; Greene, 2005)
  • Explanatory variables for inefficiency (Kumbhakar et al. 1991; Wang, 2002; Wang & Schmidt, 2002; Greene, 2005)
Econometrics

• True fixed-effects (TFE) model (Greene 2005): a SF approach for panel data with fixed effects – allows to disentangle time-varying inefficiency from individual unobserved heterogeneity

• Frontier

\[
\ln(y_{it}) = \beta_1 \ln(k_{it}) + \beta_2 \bar{T}_{it} + \beta_3 \bar{T}_{it}^2 + \beta_3 \bar{P}_{it} + \beta_4 \bar{P}_{it}^2 + \beta_5 t + \theta_i + \nu_{it} - u_{it}
\]

• Inefficiency

\[
\sigma_{it}^2 = \lambda_i + \lambda_1 \left[ \frac{T_{it} - \bar{T}_{it}}{\tau_t} \right] + \lambda_2 \left[ \frac{P_{it} - \bar{P}_{it}}{\pi_t} \right]
\]

\[
E(u_{it}) = \sigma_{it} \sqrt{2/\pi} ; \text{Var}(u_{it}) = \sigma_{it}^2 (1 - 2/\pi)
\]
Estimation

• Computationally cumbersome, issues with convergence in ML estimation
• Stata, SFMODEL (Kumbhakar et al. 2015)
  • Avoid SFCROSS and particularly SFPANEL (Belotti et al. 2013)
• Exponential as robustness
• Squared anomalies, asymmetries as robustness
• Heterogeneity in income vs climate

• Key concern: Non-stationarity
<table>
<thead>
<tr>
<th>Frontier</th>
<th>Capital</th>
<th>0.616***</th>
<th>(0.008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td></td>
<td>0.181***</td>
<td>(0.024)</td>
</tr>
<tr>
<td>Temperature squared</td>
<td></td>
<td>-0.006***</td>
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<td>Rainfall</td>
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<tr>
<td>Temp * poor</td>
<td></td>
<td>0.325**</td>
<td>(0.147)</td>
</tr>
<tr>
<td>Temp squared * poor</td>
<td></td>
<td>-0.005*</td>
<td>(0.003)</td>
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Baseline results - Frontier

• Shallow parabola in temperature for rich countries, steep one in poor countries

• Rainfall has no effect

• Robust, except for definition of poor
Further tests

- Same qualitative results if interaction of temperature with capital per worker replaces poverty dummy
- Polity IV does not do much
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<th></th>
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<td>Rain * hot</td>
<td></td>
<td></td>
<td>0.098</td>
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Baseline results - Inefficiency

• Temperature and rainfall shocks are bad for poor countries
  • Not for hot countries, poor countries
• Positive effect of unusual rain in rich countries
  • Puzzling
  • Perhaps GDP v NDP
  • Perhaps inflation
Non-stationarity

• Both the dependent variable and the variables of interest are non-stationary
• Both error terms are assumed to be stationary
• Unfortunately, there are no tests for cointegration for stochastic frontier models, let alone panel cointegration
• Stochastic frontier panels are hard to estimate, so we opted for
  • country fixed effects, a joint linear trend in the frontier
  • country fixed effects in inefficiency
residual averaged across countries
inefficiency averaged across countries
total error
Remedies

• Recast model as error-correction

• Sample split
  • Split sample by decade
  • Re-estimate model
  • Shrink decadal estimates

• If non-stationarity would influence parameter estimates, the shrunk parameters would be different
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<th>Decadal split, shrunk</th>
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Error correction

• Climate in equilibrium, weather in growth
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  + \beta_5 t + \theta_i + \nu_{it}
  \]

\[
  \Delta \ln(y_{it}) = \lambda_1 \hat{\nu}_{it} + \lambda_2 \left| \frac{T_{it} - \bar{T}_{it}}{\tau_t} \right| + \lambda_3 \left| \frac{P_{it} - \bar{P}_{it}}{\pi_t} \right| \\
  + \lambda_4 t + \vartheta_i + \upsilon_{it}
  \]

• Long-run
  • Parabolic relationship with temperature, stronger in poor countries
  • Too much water is bad for rich countries, too little for poor countries

• Short-run
  • Rainfall shocks reduce growth in poor countries
  • No effect in rich countries
Findings

• Climate affects the production potential of economies
• Weather affects economic activity
• Stronger effects in poor countries
Implications

• Schelling Conjecture holds

• Studies that regress income on climate should account for weather-induced heteroskedasticity

• In a short panel or cross-section, there is a good chance of bias

• Studies that regress growth on weather should account for lagged variables, because if our specification is correct, economies bounce back quickly
Thank you!