EC1340 Topic #5

Climate damage II

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Outline

1. Dell, Jones, Olken 2008
2. Schlenker and Roberts (2009)
3. climate and future consumption
4. Conclusion

Climate Change and Economic Growth: Evidence from the Last Half Century

Dell, Jones, Olken (2008)

This paper estimates the effects of climate change on the GROWTH of gdp, rather than it's level. It's a pretty tough read and I'll go through it pretty carefully here, it's optional.

Data:

- 50 years of average annual temperature and rainfall by country.
- Annual gdp data for 136 countries with at least 20 years of data in Penn World Tables.

Notation:

- countries $i = 1, \ldots, 136$
- T_{it} temperature(rainfall), country i, year t.
- Y_{it} gdp country i year t
- $g_{it} = \frac{Y_{it} - Y_{it-1}}{Y_{it-1}}$ growth rate of gdp in year t country i

We want to know the relationship between g and T.
Consider estimating,

$$g_{it} = B_0 + B_1 T_{it} + \epsilon_{it}$$

What if both temperature and technology trend upwards over time?(they do) Then we have

$$T_{it} = C_0 + C_1 t + \tau_{it}.$$

t still indexes years, C_1 is the constant annual increase in T, and τ_{it} is country I's annual variation around the trend. Also, let

$$\epsilon_{it} = D_i t + \mu_{it}.$$

D_i is the constant annual contribution of technological progress to growth and μ_{it} the contribution of other unobserved factors to gdp growth for country i, year t.

This means that the true model describing the relationship between growth and temperature consists of three equations

$$g_{it} = B_0 + B_1 T_{it} + \epsilon_{it} \tag{1}$$

$$T_{it} = C_0 + C_1 t + \tau_{it} \tag{2}$$

$$\epsilon_{it} = D_i t + \mu_{it}. \tag{3}$$

Solving the second for t gives

$$t = (T_{it} - \tau_{it} - C_0)\frac{1}{C_1}$$

substituting this into the third equation gives,

$$\epsilon_{it} = D_i(T_{it} - \tau_{it} - C_0)\frac{1}{C_1} + \mu_{it}.$$

substituting this into the first equation gives

$$g_{it} = B_0 + B_1 T_{it} + D_i((T_{it} - \tau_{it} - C_0)\frac{1}{C_1} + \mu_{it})$$
$$g_{it} = B_0 + (B_1 + \frac{D_i C_0}{C_1})T_{it} + \left[\frac{(-\tau_{it} - C_0)D_i}{C_1} + \mu_{it}\right]$$

Thus, if we estimate

$$g_{it} = \hat{B}_0 + \hat{B}_1 T_{it} + \hat{\epsilon_{it}} \tag{4}$$

We'll end up with $\hat{B}_1 = B_1 + \frac{D_i C_0}{C_1}$, and we confound the effects of technological improvement with temperature increases. Not at all what we want.

To see how to get around this, substitute the second and third equation of our model into the first,

$$g_{it} = B_0 + B_1(C_0 + C_1 t + \tau_{it}) + (D_i t + \mu_{it}).$$

Rearranging, we see that

$$g_{it} = B_0 + (B_1 C_1 + D_i)t + B_1(C_0 + \tau_{it}) + \mu_{it}$$

so, to fix this problem, 'control for' time trend, by estimating (note trick, use T_{it} for $C_0 + \tau_{it}$),

$$g_{it} = B_0 + B_1 t + B_2 T_{it} + \epsilon_{it}.$$

Actually, Dell et al use annual indicator variables.
Let θ_t be 1 for year t, zero otherwise. Then we have,

$$g_{it} = \sum_{t=1}^{20} B_{1t}\theta_t + B_2 T_{it} + \epsilon_{it}.$$

This is a more general way to control for time trends which is based on a more general expression for the second equation in which T_{it} doesn't necessarily grow linearly.

What if hot countries grow slowly and experience faster(slower) temperature growth? In this case, it is initial level of heat that causes growth rate, not change. Note that hot countries tend to grow more slowly AND tend to be near the equator where climate is changing less rapidly.
To understand this problem, start by writing the math. Let

$$T_{it} = T_i + \tau_{it},$$

for $T_i = \frac{1}{20}\sum_{k=1}^{20} T_{it}$ is i's mean temperature. Also let

$$\epsilon_{it} = \mu_i + \eta_{it}.$$

μ_i is country i's unobserved propensity to grow. We're worried that T_i and μ_i are both high/low at the same times, e.g. $T_i = D_0\mu_i$. In this case, we'd have $cov(T_{it}, \epsilon_{it}) \neq 0$.

Substituting the last two expressions into our basic estimating equation,

$$\begin{aligned} g_{it} &= B_0 + B_1 T_{it} + \epsilon_{it} \\ &= B_0 + B_1 (T_i + \tau_{it}) + (\mu_i + \eta_{it}) \\ &= (B_0 + B_1 T_i + \mu_i) + B_1 \tau_{it} + \eta_{it} \\ &= B_i \theta_i + B_1 \tau_{it} + \eta_{it} \end{aligned}$$

where θ_i is 1 for country *i* and zero otherwise. In this case, $B_i\theta_i$ reflects country *i* growth due to initial temperature and background rate of progress. B_1 measures the sensitivity of growth rate to deviations from temperature trend.

Altogether, we have

$$g_{it} = B_i\theta_i + \sum_{t=1}^{20} B_{1t}\theta_t + B_2 T_{it} + \epsilon_{it}.$$

and B_2 is the parameter of interest.

Estimating this equation, Dell et al. find that a one degree Celsius increase causes about a 1% decrease in the growth rates of poor countries, and has no effect on rich countries.

A poor country is one in the bottom half of the per capital gdp distribution.

Rich country growth rates are 2-3%/year Country weighted annual growth rates were about 5% year for Africa between 2000-2010. My calculation, from OECD data

This means that 3 degrees warming by 2100 causes 3% decrease in annual growth rate against 5% base, and climate change almost completely offsets economic growth in poor countries! This is a huge effect.

Issues:

- Cross-sectional relationship between gdp and climate also shows a large negative relationship between temperature and gdp.
- These are short-run estimates, so no adaptation. This means it overstates effect of climate on growth. They try to address this, but ...
- Rich country findings consistent with Mendelsohn et al.

Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change

Look at crop yields as a function of temperature for three most valuable US crops, corn, soybeans, cotton. (The US is the worlds biggest exporter of agricultural products).

Data: crop yields by county for each crop, 1950-2005, and HOURLY temperatures and rainfall by county for the same period. Let $k = 1, .., K$ denote three degree Celsius 'bins', bin 1 [0,3), bin 2 [3, 6), etc. Assign each county hour to a bin according to it's temperature.

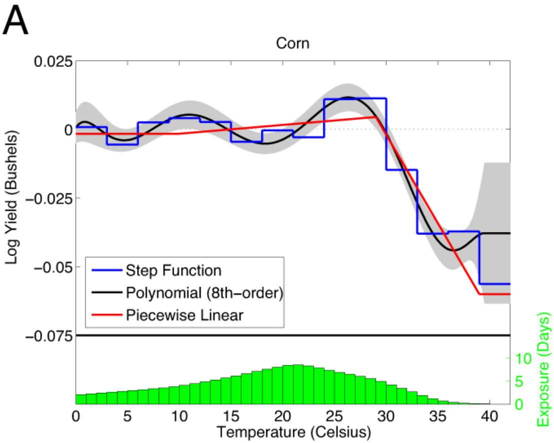
- D_{ikt} county i hours in temperature bin k in year t (really ln of hours).
- y_{it} county i year t yield of corn, soybeans, cotton, e.g., bu./acre.

Now estimate,

$$y_{it} = B_1 D_{i1t} + B_2 D_{i2t} + \ldots + B_K D_{iKt} + A_0 + \epsilon_{it}.$$

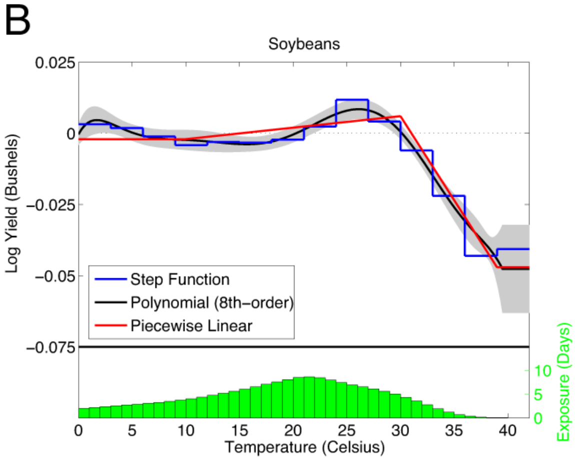
B_k is effect on yield of one extra hour of time in bin k averaged over counties and years.
If we plot the B_k against the temperature in bin k, we get...

Schlenker and Roberts (2009)



Schlenker and Roberts, PNAS 2009 fig 1

Schlenker and Roberts (2009)



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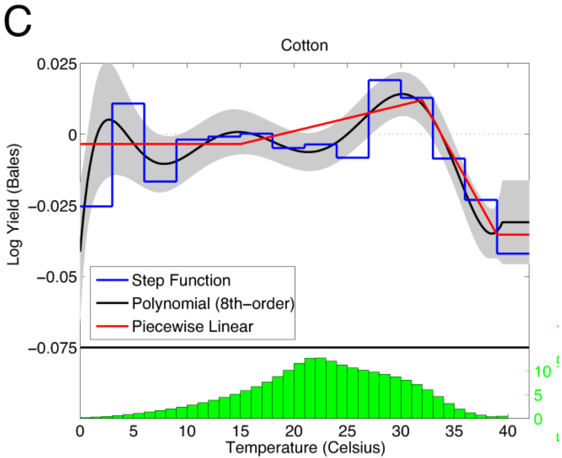

Schlenker and Roberts, PNAS 2009 fig 1

Yields go down dramatically as exposure to high temperatures goes up. The threshold is 29-32 degrees Celcius.
Given these estimates, and projections for climate under different warming scenarios, we can ask what happens to yields as climate changes: reduction of 30-46% with lots of mitigation, 63-82% without.

Issues:

- We're estimating a production function, so endogeneity issue we discussed earlier is relevant. Maybe bad farmers buy land prone to hot spells?
- This is very short run. In particular, no crop substitution is allowed. Note that threshold for different crops is at different places, which suggests that crop substitution, from corn to soybeans and cotton would matter, maybe a lot.
- Mendelsohn et al also find evidence for non-linear effects of warming.
- Compare these results with the rapid adaptation that Rhode and Olmstead document

The relationship between climate and future consumption I

- Projections used in Stern and Nordhaus models predict about 3% decline in the level gdp for 3 degrees of warming, with variation between 0-6% (more or less). For more warming, damage goes up fast.
- These projections are predominantly based on studies like the Mendelsohn et al study.
- Pay attention to time scale when reading, e.g., Stern and Hansen. Catastrophes seem to start with 5+ degrees of warming, which is probably 200 years away. IPCC and Nordhaus focus on 100 year horizon.

The relationship between climate and future consumption II

- There is reason to be suspicious of these forecasts. Dell et al find large effect of climate on growth rates for poor countries. Schlenker and Roberts find big effects on yields past a certain temperature threshold.
- With this said, it is striking that there is so little agreement in the literature on the SIGN of the effects of climate change. This suggests to me that, in fact, the effects are small for developed countries.

The relationship between climate and future consumption III

Recalling our statement of the the global warming problem,

$$\max_{s,M} u(c_1, c_2) \tag{5}$$

$$\text{s.t. } W = c_1 + s + M \tag{6}$$

$$c_2 = (1 + r)s - \gamma(T_2 - T_1)s \tag{7}$$

$$E = \frac{\rho_5 c_1 \times \rho_3 s}{\rho_4 M} \tag{8}$$

$$P_2 = \rho_0 E + P_1 \tag{9}$$

$$T_2 = \rho_1 P_2 + T_1 \tag{10}$$

We're after γ. With no warming then the second constraint above

The relationship between climate and future consumption IV

is

$$c_2^A = (1 + r)s$$

with three degrees of warming it is,

$$c_2^B = (1 + r)s - \gamma s3.$$

The relationship between climate and future consumption V

If a 3 degree increase in temperature decreases output by 3% then $c_2^A = 0.97c_2^B$. Using these relationships, we have

$$
\begin{aligned}
0.97c_2 &= (1+r)s - \gamma(3)s && (11)\\
\implies 0.97[(1+r)s - \gamma(0)s] &= (1+r)s - \gamma(3)s && (12)\\
\implies 0.97[(1+r)s] &= (1+r)s - \gamma(3)s && (13)\\
\implies 0.01(1+r) &= \gamma && (14)
\end{aligned}
$$

So γ is about 0.01. (But Nordhaus et al generally use a non-linear relationship like the ones I plotted earlier).

Future consumption price of current emissions I

Here is how we can use all of these numbers to try to guess at the future consumption price of current emissions:

- Current world gdp is about 6.3×10^{13} (63 trillion) 2010 USD

  http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf
- If the world economy grows at 3%/year for the next 100 years, world gdp will be $6.3 \times 10^{13} \times (1.03)^{100} = 12 \times 10^{14}$ 2010USD.
- 3% of this amount is 3.6×10^{13}\$
- 3 degrees of warming causes a 3% decrease in the level of gdp (about)
- 3 degrees of warming is caused, in 100 years, by doubling CO_2 concentrations from 280 to 560ppm.

Future consumption price of current emissions II

- Each ppm of concentration requires 2.12 Gt C in the atmosphere and 3.8 Gt C emmissions. So increasing atmospheric concentrations of CO_2 to 560 ppm requires $280 \times 3.8 = 1064$ Gt C emissions.
- Thus, 1064 Gt C of emissions causes a loss of 3.6×10^{13}\$ in 100 years.
- Dividing, 1 Gt C causes about 3.4×10^{10}\$ damages.
- Thus, 1 t C causes about $3.4 \times 10 = 34$\$ of damages in 2100 (and in 2101, 2012, ...).
- 1 t CO_2 emissions results from 435 liters of gasoline. Thus, we get about 1/3.7 t C emissions from 435 liters. It follows that a 50 liter tank of gas causes about. $\frac{50}{435} \times \frac{1}{3.7} \times 34 = 1.06$\$ of damage in 2100 (and 2101, 2012,....).

Future consumption price of current emissions III

What we're doing here is to use the four constraints in our model to solve for future consumption as a function of emissions.

The next step is to compare present and future consumption.