Natural resources and economic growth

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Introduction to Economic Growth

Resources and modern growth

Economies use resources in addition to capital, labor

$$Y_t = K_t^{\alpha} E_t^{\beta} (A_t L_t)^{1-\alpha-\beta} \tag{1}$$

where E_t is a flow of resources (think “energy”) used in addition to other factors. Let capital and productivity evolve as usual.

Resource dynamics

There is a stock of resources, R, from which we draw E_t

$$dR = -E_t. \tag{2}$$

so that the stock declines over time. In this sense it is non-renewable. Think R is oil in the ground, E is oil used. Let

$$s_E = \frac{E_t}{R_t} \tag{3}$$

be the extraction rate.

Resource dynamics

The growth rate

$$g_R = -s_E,$$

and therefore

$$g_E = -s_E$$

or the amount used is declining over time. Could add discovery which raises R and offsets this.

Growth with resources

Let

$$Y_t = K_t^{\alpha} (B_t L_t)^{1-\alpha} \tag{4}$$

where

$$B_t = A_t^{\frac{1-\alpha-\beta}{1-\alpha}} \left(\frac{E_t}{L_t} \right)^{\frac{\beta}{1-\alpha}} . \tag{5}$$

We know how a model with "productivity" of B_t evolves (think Solow model)

$$g_y^{ss} = g_B .$$

Growth with resources

What is g_B?

$$\begin{aligned} g_B &= \frac{1-\alpha-\beta}{1-\alpha} g_A - \frac{\beta}{1-\alpha} s_E - \frac{\beta}{1-\alpha} g_L \\ &= \left(1 - \frac{\beta}{1-\alpha}\right) g_A - \frac{\beta}{1-\alpha}\left(s_E + g_L\right). \end{aligned} \tag{6}$$

or the growth rate along the BGP depends on productivity growth, g_A, and the extraction rate, s_E. Also depends negatively on g_L (kind of like Malthusian model).

Race of productivity and resources

Whether growth is positive along a BGP depends on if

$$g_A > \frac{\frac{\beta}{1-\alpha}}{1 - \frac{\beta}{1-\alpha}}(s_E + g_L) \tag{7}$$

which means faster extraction or higher population growth makes sustained growth harder to achieve. However, this

doesn't mean $s_E \to 0$ is a great policy, because then $E_t \to 0$ and GDP per capita will go to zero. There are trade-offs

Is energy scarce?

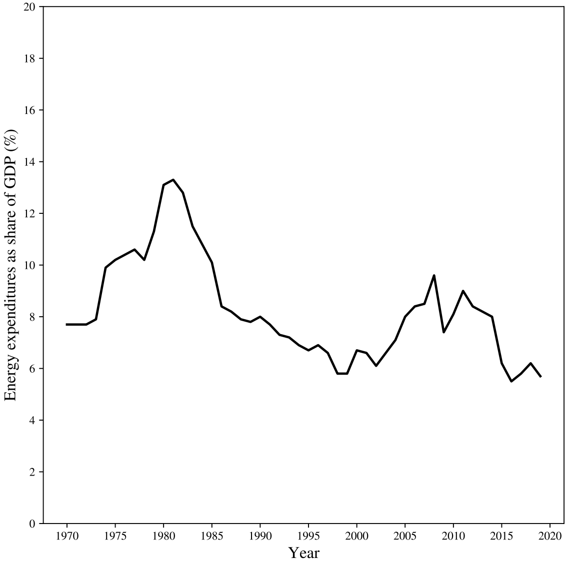
The model predicts that E_t declines over time, using less "energy". But does that mean energy is scarce? Depends on the price. As with labor and capital, E_t is a factor paid a marginal product

$$\beta \frac{Y_t}{E_t} = p_{Et}.$$

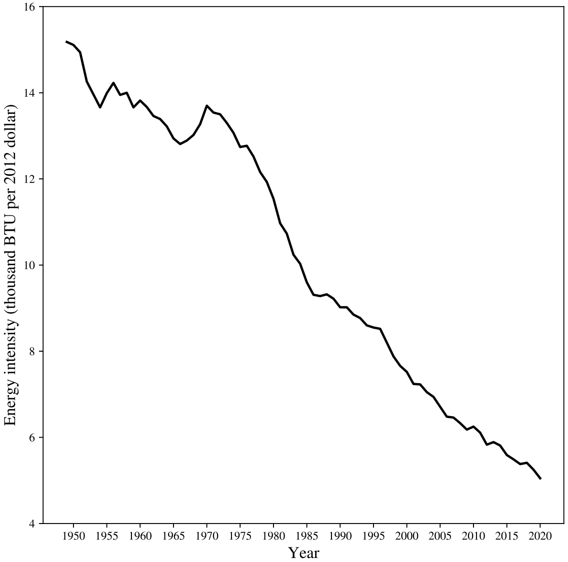
so the share of GDP going to E_t should be

$$\frac{p_{Et} E_t}{Y_t} = \beta. \tag{8}$$

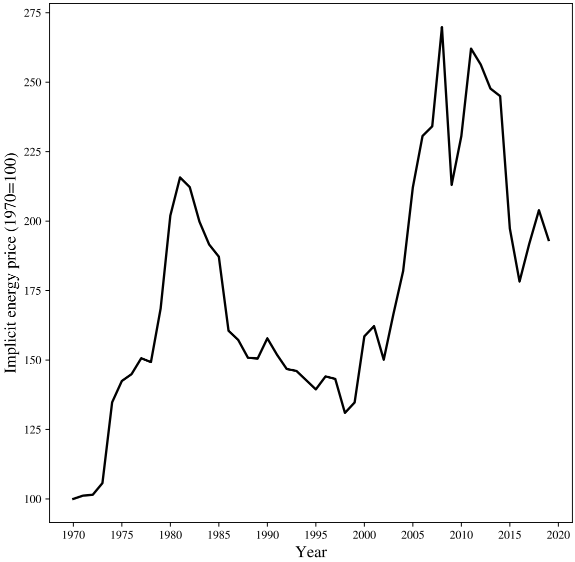
Energy share



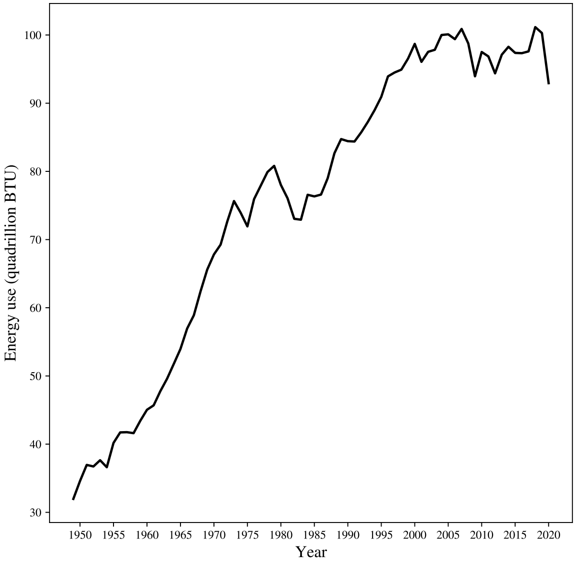
Energy intensity, E_t/Y_t



Implied price, p_E



Total energy use



Declining share

But is the energy share declining? An alternative production structure would give us

$$Y_t = \left(K_t^{\rho} + (A_t E_t)^{\rho}\right)^{1/\rho}, \tag{9}$$

that ignores labor.

- ρ determines how substitutable capital and energy are.
- If $0 < \rho < 1$ then they are easy to substitute
- If $\rho < 0$ then they are complements (hard to substitute)
- A is the productivity of energy specifically

Energy Share

With this model energy's share of GDP is

$$\frac{p_{Et}E_t}{Y_t} = \left(\frac{A_t E_t}{Y_t}\right)^{\rho}.$$

- We know E/Y went down
- If $\rho > 0$ (substitutes) then this explains the declining share
- If $\rho < 0$ (complements) then share should go up, unless A increased by a lot
- Seems like complements is more accurate (think a car and gas), so energy productivity A must have gone up?

The choice of s_E

Like other rates, extraction is a choice. What might that decision look like?

$$U_t = (c_t - \bar{c})^{1-\rho} R_t^{\rho} \tag{10}$$

- People care about consumption, c
- There is some minimum consumption, $\bar{c}$, that they need to have
- People care about the stock of resources, R
- That could be value of oil remaining in the ground
- Or that could be value of a forest or clean water

Marginal utiles

For consumption

$$MU_c = \frac{(1-\rho)U_t}{c_t - \overline{c}} = (1-\rho)\frac{R_t^{\rho}}{(c_t - \overline{c})^{\rho}}. \tag{11}$$

and for resources

$$MU_R = \frac{\rho U_t}{R_t} = \rho\frac{(c_t - \overline{c})^{1-\rho}}{R_t^{1-\rho}}. \tag{12}$$

In both cases, the MU goes down as you get more of the thing.

Optimizing

Set ratio of MU equal to ratio of prices

$$\frac{MU_R}{MU_c} = \frac{P_{Rt}}{P_{ct}} \tag{13}$$

as usual. But what are the prices?

Production and prices

Let

$$y_t = E_t^{\beta} A_t^{1-\beta} L_t^{-\beta}, \tag{14}$$

be production per capita, and let $c_t = y_t$ (no capital). Also, the resource evolves

$$dR = -E_t, \tag{15}$$

So there is a trade-off in using E_t. It raises consumption but lowers the resource stock.

Production and prices

$$\frac{P_{Rt}}{P_{ct}} = \frac{\beta y_t / E_t}{1}.$$

- The price of consumption is 1. It takes one unit of output to produce one unit of consumption.
- The price of the resource is $\beta y_t / E_t$. You have to sacrifice that amount of output (the MP of E) to keep one unit of R

The optimal choice

Solve for

$$\frac{\rho(c_t - \overline{c})}{(1-\rho)R_t} = \beta \frac{y_t}{E_t}.$$

which is re-arranged into

$$s_{Et} = \frac{E_t}{R_t} = \beta \frac{1-\rho}{\rho} \frac{y_t}{y_t - \overline{c}}. \tag{16}$$

and note it depends in two ways on the size of y_t.

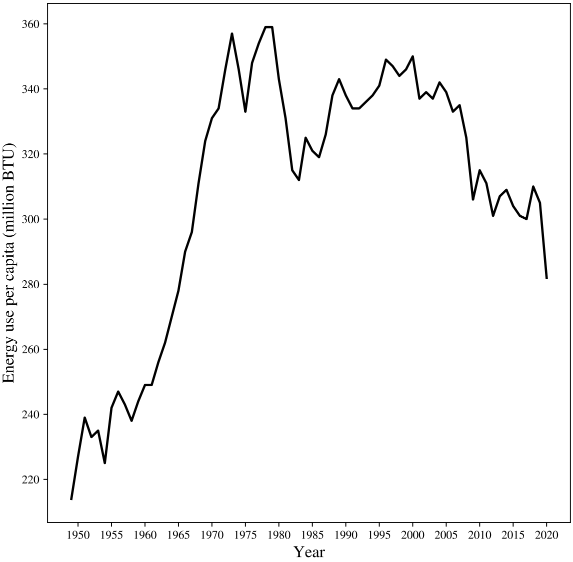
The environmental effects of growth

With

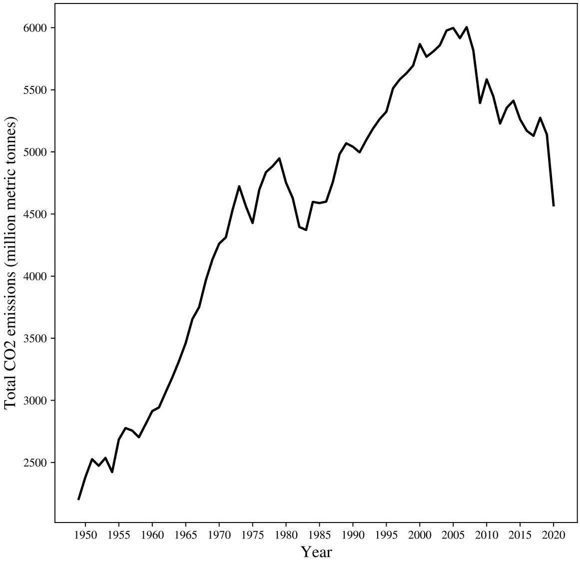
$$s_{Et} = \beta \frac{1-\rho}{\rho} \frac{y_t}{y_t - \bar{c}}. \tag{17}$$

- If $y_t \to \bar{c}$ - poverty - then s_{Et} is big
- It makes sense to sacrifice R to get more consumption
- But as y_t gets very big via economic growth s_{Et} goes down
- The additional consumption isn't worth very much compared to the loss of R
- It implies that environmental quality can improve with economic growth
- Think energy efficient cars/appliances, recycling, low-impact products, carbon offsets, etc..

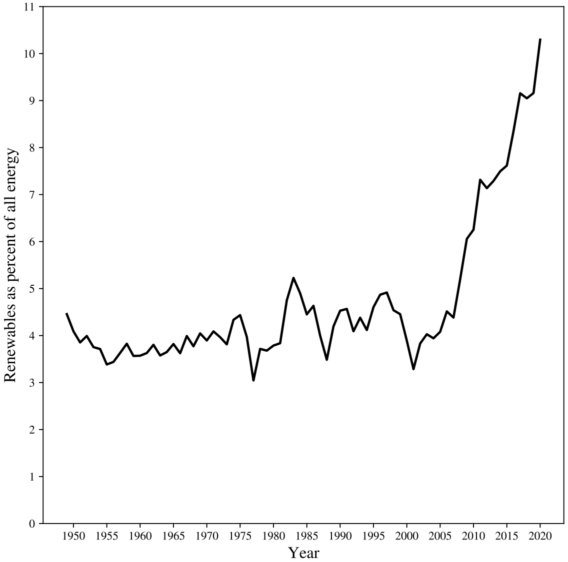
Energy use per capita



Total CO2 emissions



Renewable percent



Air pollutants