Energy Policy, Food and Climate Change

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http://farm3.static.flickr.com/2342/2453132258_80704150e2_o.jpg

1. Motivation

- This paper is about the role of renewable energy for sustainable growth and the mitigation of climate change
  - In particular, for an application, we focus on the optimal substitution of bio-fuels for fossil fuels in transport
  - However, there is a serious concern about the indirect land use change impact of bio-fuels if arable land is displaced
  - For instance, the grain crops devoted to bio-fuels in the US in 2009 (one quarter) could feed 330 Mio people (according to the Earth Policy Institute, Washington)

1. Motivation

- Research Issues and Strategy
  - The objective of the paper is to discuss the long run factor substitution in energy production to assure for sustainable growth
  - Moreover, we emphasize the issue of ILUC modeled in terms of the food-bio-fuels trade-off
  - For this purpose, we employ an enhanced version of a Romer-Type endogenous growth model by incorporating both, fossil fuels and bio-fuels simultaneously,
  - In addition to land input, used competitively

1. Motivation

- Preliminary Results
  - We provide the Social Planner Solution, as well as some implications of the FOC for the use of the energy resources and the trade-off in the land use (work in progress, results preliminary, Social Planner Sol.)
  - However, model not to be solved analytically, numerical simulation necessary

2. The Model – Basic Setup

- Romer-type endogenous growth model (e.g. Aghion-Howitt)
- Conventional setting:
  - final output Y and consumption C
  - consumers maximize discounted lifetime utility u
  - capital accumulation through savings $\dot{K}$
  - energy saving technical progress H
  - traditional factors of production: labor L, capital K, land T
  - Further factors of production: Intermediates X in form of renewable resources R and non-renewable resources Z
  - energy saving technical progress fostering growth
  - environmental stock E and emissions

2. The Model – Basic Setup

- Modeling:
  - Land Use
    - Competing uses of land input for food and fuels production
    - Fixed supply $\overline{T} = 1$, share TY used for food, share TA for biofuels production
    - Land used for biofuels is increasing the rate of regeneration $\eta_a = \eta_a(TA)$, with $d\eta_a / dTA > 0$
  - Labor Use
    - Competing uses of labor input for food and knowledge production
    - Fixed supply $\overline{L} = 1$, share LY used for food, share LH for knowledge production

2. The Model – Basic Setup

- Final output:

$$Y = F(LY, K, TY, X)$$

- Capital accumulation:

$$\dot{K} = Y - C - \epsilon K$$

  - with the depreciation rate ϵ
- Intermediates
  - Fossil fuels and biofuels produce intermediates - transportation

$$X = X(G(Z, R), H)$$

  - H is the endogenous stock of knowledge

$$\dot{H} = h(LH) \cdot H$$

  which enhances the efficiency of the energy use over time,

  engine for growth

2. The Model – Basic Setup

- Non-renewable resource stock (fossil fuels):

$$\dot{S} = -Z$$

- Renewable resource stock (biofuels):

$$\dot{A} = \eta_a(TA) \cdot A - R$$

where $\eta_a > 0$ is the rate of natural regeneration

- Lifetime utility:

$$U = \int_0^\infty u(C, E) \cdot e^{-\rho \cdot t} dt$$

2. The Model – Basic Setup

- The environment
  - Extraction of resources, both, the non-renewable and the renewable resource, affects environmental quality
  - fossil fuels always damage the environment more than biofuels.
  - Standard modeling (following Aghion-Howitt)

$$\dot{E} = -Z - \eta_E E - \varpi R \text{ where } E < 0$$

  - where $0 \leq \varpi < 1$ is the rate of pollution generated by the biofuel
  - Sustainability condition: environmental quality must not decrease

$$E_{\min} < E_t < 0$$

  - $E_{\min}$ critical threshold level,
  - η_e exogenous rate of regeneration of E

3. Social Planner Solution

- The social planner maximizes the representative household‘s intertemporal utility subject to the given restrictions.
  - The corresponding present value Hamiltonian is:

$$Ham = u(C,E)\cdot e^{-\rho\cdot t} + \pi(Y - C) + \psi(h(LH)\cdot H)$$
$$+ \theta(\eta_a(TA)A - R) - \lambda Z + \mu(-Z - \eta_e E)$$

  - This allows for deriving the first order conditions for the control variables *C*, *L*, *T*, *R* and *Z*, and the state variables *K*, *H*, *S*, *A* and *E*. In addition the transversality conditions must hold.

3. Social Planner Solution

- Resource Use
  - Usual first-order conditions for controls C, L, and state variables K, H
  - FOC for fossil and biofuels, respectively

$$\pi \cdot Y_Z = \lambda + \mu$$

$$\pi \cdot Y_R = \theta + \mu \cdot \varpi$$

  - Marginal value product of the resource (in terms of discounted utility) must equal its shadow value, hence the social rate of return.

3. Social Planner Solution

- But: The social rate of return may differ significantly from the physical rate
  - The shadow value of fossil fuels is incorporating the user cost of the environment, given by μ, in addition to the shadow value of the stock, due to environmental degradation.
  - The biofuel incorporates only $\varpi \cdot \mu$ with $0 < \varpi < 1$.
- Hotelling rules for the extraction of natural resources are given by:
  - Renewable resource: $g_{YR} = \frac{\dot{Y}_R}{Y_R} = Y_K - \frac{\theta \cdot \eta_a + \varpi \cdot (\eta_E - u_E)}{\theta + \varpi \cdot \mu}$

    if $\varpi = 0$ $\quad g_{YR} = Y_K - \eta_a$
  - Non-renewable resource: $g_{YZ} = \frac{\dot{Y}_Z}{Y_Z} = Y_K + \frac{\eta_E \cdot \mu - u_E}{\lambda + \mu}$

3. Social Planner Solution

- Factor substitution
  - Tentative results: values not given explicitly!
  - For bio-fuels: Physical rate of return is set below the social rate of return due to the regeneration capacity of the stock (which in turn is equal to the net steady state growth rate of renewable stock value)

    $$g_{YR} < Y_K$$

  - For fossil fuels: Physical rate of return must be above the social rate of return because of the enormous environmental damage generated as well as the degradation of the stock

    $$g_{YZ} > Y_K$$

  - Hence, bio-fuels must continuously substitute for fossil fuels
  - This results hold whatever share of land is devoted to the production of bio-fuel

4. Indirect Land Use Change

- Land Use
  - The food-energy trade-off is given by

$$\pi \cdot Y_{TY} = \theta \cdot \eta_{a\,(TY)} \cdot A$$

    The marginal value product of land in food production must be balanced by the marginal value product of land in biofuels production.
  - Factor substitution in transport is constrained by food shortage, growth of intermediates as well as output must be slowed down.
  - Supports the call for alternative productions of biofuels which do not compete with food production

5. Numerical Simulation

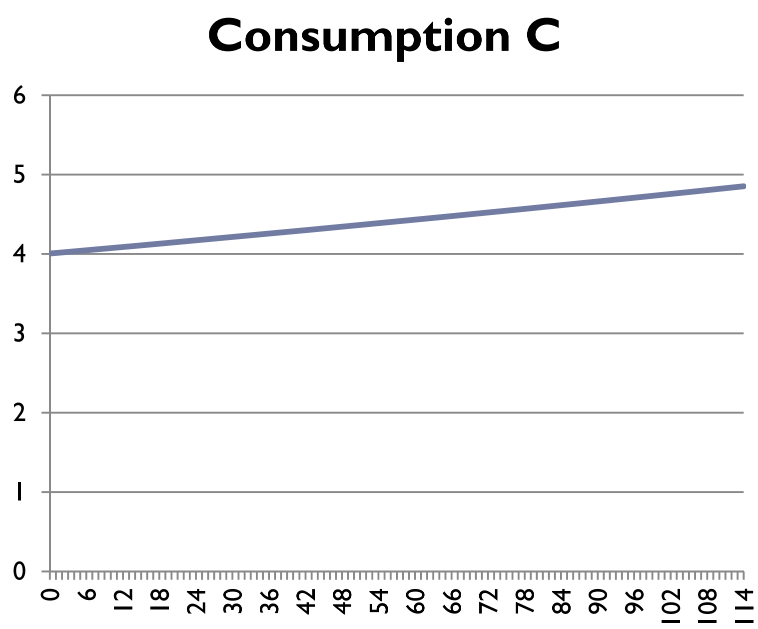
- Specifying the main functions:
  - Separable utility function, of CRRA-typ
    $$u(C_t, E_t) = \frac{C_t^{1-\beta} - 1}{1-\beta} - \frac{(-E_t)^{1+\sigma} - 1}{1+\sigma}$$
  - Cobb-Douglas-type production function
    - All inputs are essential.
    $$Y_t = LY_t^{\alpha 1} \cdot K_t^{\alpha 2} \cdot TY_t^{\alpha 3} \cdot X^{\alpha 4}$$
  - Production function for intermediates
    $$X_t = \left(\left(Z_t^{\frac{\kappa-1}{\kappa}} + R_t^{\frac{\kappa-1}{\kappa}} \right)^{\frac{\kappa}{\kappa-1}} \right)^{\chi} \cdot H_t^{1-\chi}$$
    - Both inputs are perfect substitutes, but using both simultaneously is not essential for production.
    - The stock of knowledge represents the growing efficiency in the use of energy and the development of new technologies to generate resources.

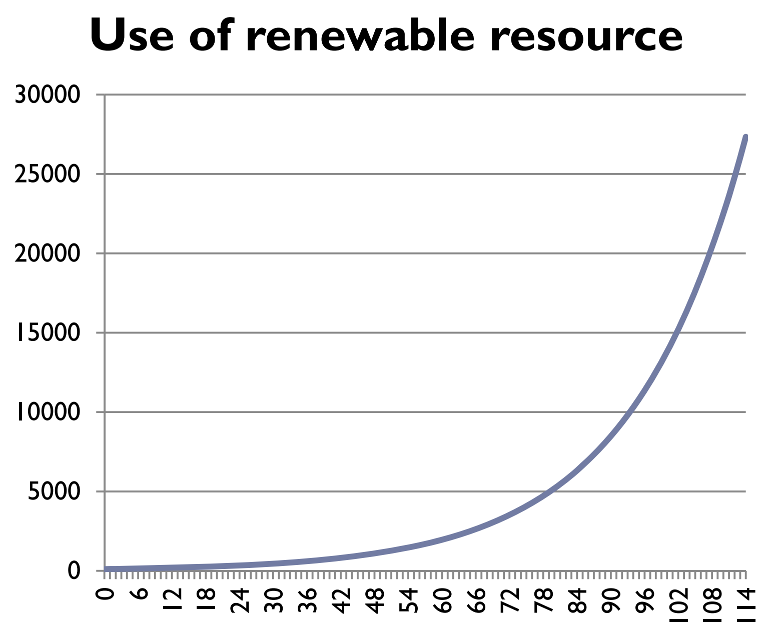
5. Numerical Simulation

- Preliminary Results
  - Results preliminary because the non-renewable resource extraction is still modeled exogenously (optimal depletion, finite time horizon)
  - Land and labor allocation: FOC imply constant land allocation and labor allocation, but optimal shares matter
    - With current calibration the share of labor endowed in the research sector is: $LH \approx 0.44$
    - The share of land endowed to the production of food is: $TY \approx 0.4$

5. Numerical Simulation

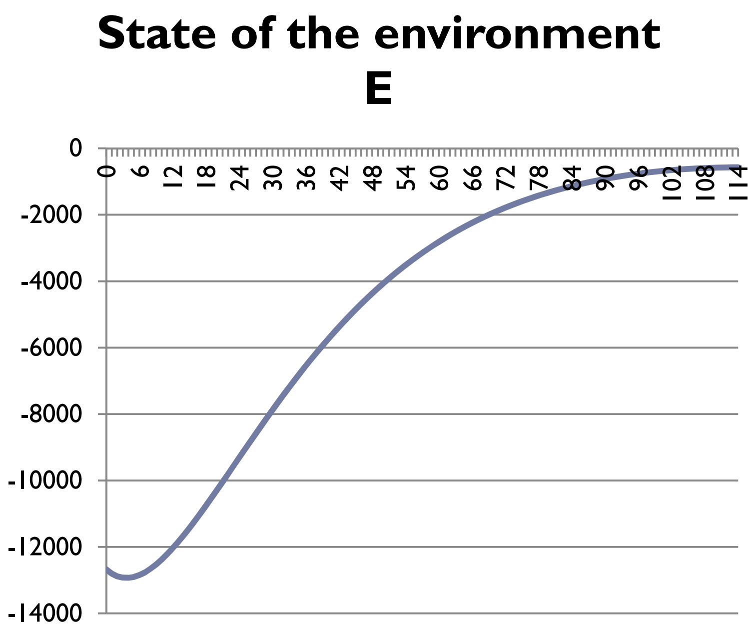
- Consumption: Growth rate of consumption throughout positive
- Growth rate of renewable resource stays pretty constant over time

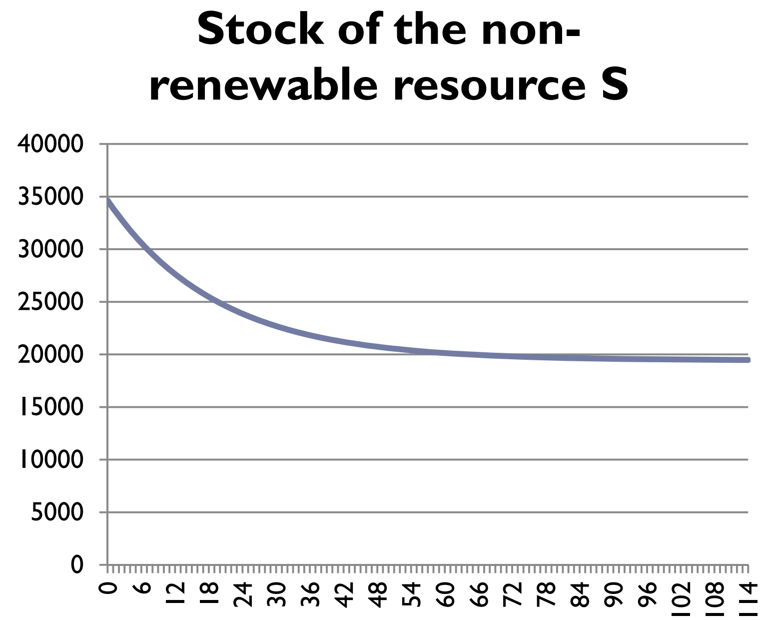




5. Numerical Simulation

- Environmental stock is growing due to decreasing non-renewable resource extraction
- Nonrenewable resource: exogenous case





6. Conclusions

- A conventional Romer-type endogenous growth model has been extended by incorporating fossil fuels and biofuels simultaneously.
- Indirect land use change considered
- Sustainable growth calls for a continuing substitution of renewable energy for fossil energy.
- But factor substitution may be very limited through the food-biofuels trade-off.
- Production should therefore be shifted to second generation biofuels.

Thank you

for your attention!