Population and environment in the economic literature

1. Introduction

2a. Static regional models
2b. Dynamic Regional Models

3a. Static global models
3b. Dynamic global models
1. Introduction

The connection between population development and use of environmental resources has been a niche area in economics. →

There are few publications examining the connection between population development or population size and the use of environmental resources using normative and positive analyses.

Types of models:

- normative vs. positive
- regional differentiation
- temporal differentiation
- endogenous population growth

Local vs. global environmental problems

Local: **direct** link between use of environmental resources and regional population development. (e.g. Migration as reaction to environmental changes)

Global: **indirect** link between population structure and global environmental problems through production and consumption pattern.

Regionally differentiated models can be static or dynamic.
2b A dynamic regional model

Dynamic interaction between renewable resources and population growth: The case of Easter Island

First populated around 400, natural resources: palm trees →

1400 population maximum of around 10,000, tremendous cultural achievements, famous stone sculptures (Moais), palm tree forest almost completely cut down

Scarcity of resources creates conflicts → only 3,000 inhabitants in 1772

**Rise and fall of Easter Island:**
Population has reached the limit of their resources

Brandner and Taylor: Malthus-Riccardo model to describe this development.
THE MODEL (general equilibrium model of renewable resource and population dynamics)

Renewable resource dynamics (Ricardo):

\[ \frac{dR}{dt} = F(R) - H(R,L) \]

- \( F \) : logistic growth of resource \( F = rR(1 - \frac{R}{K}) \)
- \( H \) : harvest depending on population and resource

Production of 2 goods:

- \( H \) : Harvest of the renewable resource
- \( C \) : aggregate good, \( C \) used as numeraire, Price = 1
Production technologies: 
\[ C(t) = L^C(t) \]
\[ H(t) = H(R(t), L^H(t)) = \alpha R(t) L^H(t) \]

Sector C – perfect competition

\[ C(t) - w(t)L^C(t) = 0 \quad \Rightarrow \quad w(t) = 1 \]

Common property resource ("price of resource good=unit cost of production")

\[ p(t)H(t) - L^H(t) = 0 \quad \Rightarrow \quad p(t) = \frac{L^H(t)}{H(t)} \]

Aggregate labour supply ("Ricardian" production function)

\[ L(t) = L^C(t) + L^H(t) = C + H/(\alpha R) \]
Derivation of the demand for the resource:

Consider a consumer with Cobb-Douglas utility function.

Equipped with one unit of labour
h individual consumption of H
c individual consumption of C

\[
\max u(h(t), c(t)) = h(t)^\beta c(t)^{1-\beta}
\]

s.t. \[ p(t)h(t) + c(t) = w(t) \]

Optimum:

\[
\begin{align*}
    h(t) &= \frac{\beta}{p(t)} w(t) = \frac{\beta}{p(t)} \\
    c(t) &= (1 - \beta)w(t) = (1 - \beta)
\end{align*}
\]
General equilibrium of $L^C(t)$ and $L^H(t)$ determined by equating aggregate supply and demand.

$$L(t)h(t) = L(t) \frac{\beta}{p(t)} = L(t) \frac{\beta}{L^H(t) / H(t)} = H(t)$$

$$\Rightarrow$$

$${L^H(t) = \beta L(t)}$$

$${L^C(t) = (1 - \beta)L(t)}$$
Harvesting function: \[ H(t) = \alpha RL^H(t) = \alpha \beta RL(t) \]

Malthusian population dynamics:

higher per-capita-output increases population growth

\[ F = \phi H(t)/L(t) = \phi \alpha \beta R \]

Population dynamics: \[ \dot{L} = L(b - d + \phi H(t)/L(t)) \]

Dynamic system:

\[ \frac{dR}{dt} = rR(1 - \frac{R}{K}) - \alpha \beta LR \]
\[ \frac{dL}{dt} = L(b - d) + \phi \alpha \beta LR \]
\[ b - d < 0 \]
Panel A: Resource Dynamics

Resource Harvest, Growth

$H = \alpha \beta LS$ (Harvest Function)

$G = G(S)$ (Growth Function)

Resource Stock, S

Panel B: Population Dynamics

$(dL/dt)/L$

$-d+F = -d + \phi \alpha \beta S$ (net fertility)

Resource Stock, S

Figure 1. A Ricardo-Malthus Steady State
Steady state analysis

\[ \frac{dR}{dt} = rR \left(1 - \frac{R}{K}\right) - \alpha \beta LR = 0 \]
\[ \frac{dL}{dt} = L(b - d) + \phi \alpha \beta LR = 0 \]

3 steady states

\((R^*, L^*) = (0,0)\)

\((R^*, L^*) = (K,0)\)

\((R^*, L^*) = \left( \frac{d - b}{\alpha \beta \phi}, \frac{r}{\alpha \beta} \left(1 - \frac{d - b}{\phi \alpha \beta K}\right) \right)\)
(R_1, L_1) saddle point
(R_2, L_2) saddle point if (R_3, L_3) exists, node otherwise
(R_3, L_3) stable node or stable spiral
(R_3, L_3) exists if (d-b)/(\phi \alpha \beta) < K
Converges to boundary solution $R=0$, $L=0$
Initial values $S=0$, $L>0$

Converges to boundary solution $R=K$, $L=0$
Initial values $S>0$, $L=0$