With exhaustible resources, can a developing country escape from a poverty trap?

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Introduction

- Standard literature on growth and exhaustible resources: Dasgupta and Heal, *RES* 1974.
  - Developed economies, or world economy.
  - Non-renewable natural resource as a production factor.
  - Capital and resource imperfect substitutes.
  - Resource input *necessary*: no production without it.
  - Optimal growth path (with a discounted utilitarian social welfare function): the shadow price of the resource stock follows the Hotelling rule, the resource is asymptotically depleted, the economy collapses asymptotically.

- Here, a developing non-renewable natural resource producer.
    - Extracts the resource from its soil in its primary sector.
    - Produces a single consumption good with man-made capital in its secondary sector.
    - Sells the extracted resource abroad.
    - Uses the revenues from the resource to buy an imported good, perfect substitute of the domestic consumption good.
    - Resource *unnecessary*: domestic production possible without it.
- Examples: when consuming and producing countries are different
    - gold, diamonds and other ores producers;
    - to some extent, oil producing countries.

Questions

- Can the ownership of non-renewable natural resources allow a poor country to make the transition out of a poverty trap?
    - Production function convex for low levels of capital and concave for high levels.
    - Conditions of occurrence of a poverty trap fulfilled (Dechert and Nishimura, *JET* 1983): the country, if initially poor, may be unable to pass beyond the trap level of capital.
    - But the country can extract its resource, sell it abroad, and use the revenues to import the good.
    - Then it can consume, or accumulate capital.
    - The idea is that a poor country with abundant natural resources could extract and sell an amount of resource which would enable it to accumulate a stock of capital sufficient to overcome the weakness of its initial stock.
- On the contrary, will the existence of the natural resource, which makes possible to consume without producing, destroy any incentive to accumulate?

The model (1)

Definitions

- Initial stock of non-renewable natural resource: $\overline{S}$.
- Extraction of this resource: R_t.
- Price at which the resource is sold abroad: P_t (in terms of the numeraire, the domestic consumption good).
- Extraction costs: $C(R_t)$.
- Revenues from the sale of the resource: $\phi(R_t) = P_t R_t - C(R_t)$.
- Allow the country to buy a foreign good, perfect substitute of the domestic good, used for consumption and capital accumulation.
- Domestic production function: $F(k_t)$.
- Depreciation rate: δ.
- Discount rate: $\rho > 0$; discount factor: $\beta = 1/(1+\rho)$.
- "Technology": $f(k_t) = F(k_t) + (1-\delta)k_t$.

The model (2)

The optimal growth problem

Central planner's program:

$$\max \sum_{t=0}^{+\infty} \beta^t u(c_t), \quad \beta \in (0,1)$$

under the constraints

$$\begin{aligned}
\forall t, c_t &\geq 0, k_t \geq 0, R_t \geq 0, \\
c_t + k_{t+1} &\leq f(k_t) + \phi(R_t), \\
\sum_{t=0}^{+\infty} R_t &\leq \overline{S}, \\
\overline{S} &> 0,\ k_0 \geq 0 \text{ given.}
\end{aligned}$$

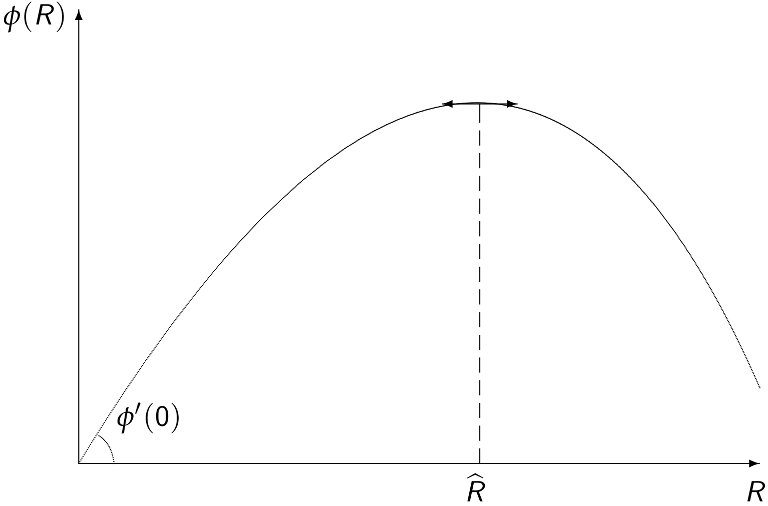
The model (3)

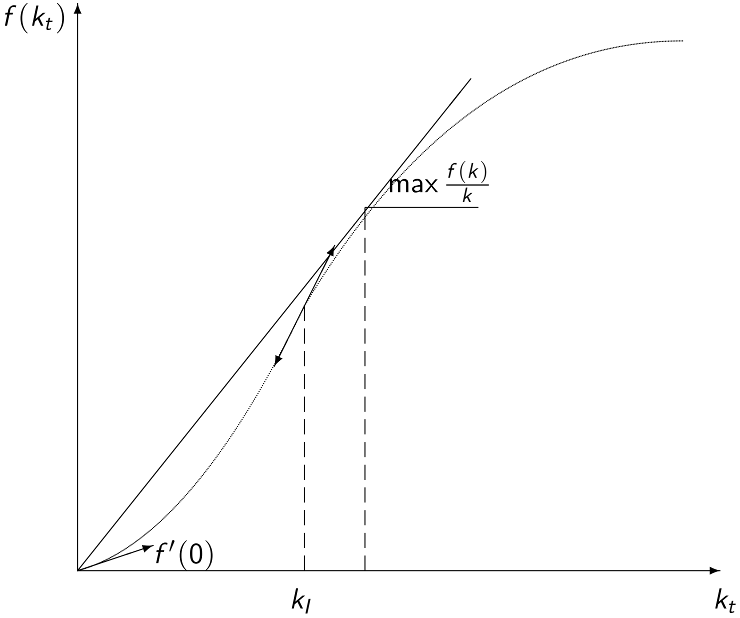
Assumptions

H1 The utility function u is strictly concave, strictly increasing, continuously differentiable in $\mathbb{R}_+$, and satisfies $u(0) = 0$, $u'(0) = +\infty$.

H2 The production function F is continuously differentiable in $\mathbb{R}_+$, strictly increasing, strictly convex from 0 to k_I, strictly concave for $k \geq k_I$, and $F'(+\infty) < \delta$. Moreover, it satisfies $F(0) = 0$.

H3 The revenue function ϕ is continuously differentiable, concave, strictly increasing from 0 to $\widehat{R} \leq +\infty$, and strictly decreasing for $R > \widehat{R}$. It also satisfies $\phi(0) = 0$.


$\phi(R)$
$\phi'(0)$
$\widehat{R}$
R



$f(k_t)$
$\max \frac{f(k)}{k}$
$f'(0)$
k_I
k_t

Properties of the optimal paths

- Along the optimal path, consumption is always strictly positive and extraction less than $\widehat{R}$, the extraction corresponding to the maximum of the revenue function.
- If the marginal revenue is infinite when the extraction becomes very small ($\phi'(0) = +\infty$), the resource is not exhausted in finite time.
- In the following, $\phi'(0) < +\infty$ (more realistic; existence of a finite choke price). The resource can be exhausted in finite time.

Euler conditions and Hotelling rule

$$(i) \quad \forall t, \quad f'(k^*_{t+1}) \leq \frac{u'(c^*_t)}{\beta u'(c^*_{t+1})} \qquad (E1)$$

with equality if $k^*_{t+1} > 0$,

$$(ii) \quad \forall t, \quad \forall t', \quad \beta^t u'(c^*_t)\phi'(R^*_t) = \beta^{t'} u'(c^*_{t'})\phi'(R^*_{t'}) \qquad (E2)$$

if $R^*_t > 0$, $R^*_{t'} > 0$, and

$$(iii) \quad \forall t, \quad \forall t', \quad \beta^t u'(c^*_t)\phi'(R^*_t) \leq \beta^{t'} u'(c^*_{t'})\phi'(R^*_{t'}) \qquad (E2')$$

if $R^*_t = 0$, $R^*_{t'} > 0$.
In the case of an interior solution, $(E1)$ and $(E2)$ imply the Hotelling rule:

$$\frac{\phi'(R^*_{t+1})}{\phi'(R^*_t)} = f'(k^*_{t+1})$$

i.e.

$$\phi'(R^*_{t+1}) = (1 + r_{t+1})\phi'(R^*_t)$$

with r_{t+1} the real interest rate. No-arbitrage condition.

To accumulate or to eat the resource stock?

- Even if the initial capital stock $k_0 = 0$, if the marginal productivity of capital at the origin is greater than the depreciation rate ($F'(0) > \delta$, i.e. $f'(0) > 1$), then the country accumulates from some date on and the resource is exhausted in finite time.
- Even if the initial capital stock $k_0 = 0$, if $F'(0) > \rho + \delta$ i.e. $f'(0) > \frac{1}{\beta}$ the country will accumulate at any period.
- When $k_0 = 0$, the same economy without natural resources never takes-off (Dechert and Nishimura, *JET* 1983).
- So, when the technology is "good" enough, the natural resource is a blessing allowing the economy to consume and accumulate.

- But under adverse conditions the country may never accumulate. It then does not exhaust its resource stock in finite time, but "eats" it and collapses asymptotically.
  - Assumption: low average productivities ($\max\{\frac{F(k)}{k} : k > 0\} \leq \delta$, i.e. $\max\{\frac{f(k)}{k} : k > 0\} \leq 1$), due to high fixed costs.
  - Then if the country's initial capital k_0 is smaller than a certain threshold, it will never accumulate, whatever the level of the resource stock.
  - For any given k_0, when impatience is high enough ($\beta < \frac{u'(f(k_0)+\phi(\widehat{R}))}{u'(\phi(\widehat{R}))}$), the country will never accumulate if the resource is very abundant.
  - For any given k_0, when impatience is low enough ($\beta > \frac{1}{f'(0)} \frac{u'(f(k_0)+\phi(\widehat{R}))}{u'(\phi(\widehat{R}))}$), the country will accumulate from period 1 on if the resource is very abundant.
  - Opposite incentive effects of the abundance of natural resources, depending on impatience: abundance encourages a patient economy to invest in physical capital, whereas it discourages an impatient one. Moreover, the smaller k_0 the larger the range of discount rates for which the country does not accumulate.

The long term: is it possible to escape from the poverty trap?

Poverty trap (Dechert and Nishimura): in an economy without natural resource,

- if $f'(0) > \frac{1}{\beta}$ (good technology relatively to impatience), then any optimal path from $k_0 > 0$ converges to a steady state $k^s > k_I$ satisfying $f'(k^s) = \frac{1}{\beta}$;
- if $f'(0) < \frac{1}{\beta} < \max\{\frac{f(k)}{k} : k > 0\}$ (intermediate technology relatively to impatience), then there exists $k^c < \widetilde{k}$, with $\frac{f(\widetilde{k})}{\widetilde{k}} = \frac{1}{\beta}$, such that if $k_0 < k^c$ then k converges to 0, and if $k_0 > k^c$, then it converges to a high steady state k^s fulfilling $f'(k^s) = \frac{1}{\beta}$;
- if $\max\{\frac{f(k)}{k} : k > 0\} < \frac{1}{\beta}$ (bad technology relatively to impatience), then if k^s is not an optimal steady state, any optimal path converges to 0, and if it is, there exists a critical value k^c with the same properties as in the case of an intermediate technology.

Here:

- Good technology relatively to impatience: obviously, same result as Dechert and Nishimura (the country is always better off with the resource than without)
- Interesting cases: intermediate and bad technologies relatively to impatience.
- Then, if the country owns a large stock of natural resource and can obtain high revenues from the extraction of a large amount of this stock at the beginning of its development path, it may be able to accumulate a stock of capital large enough to escape the proverty trap.

Intermediate technology relatively to discounting (1)

- Assumptions:
  - $f'(0) \leq \frac{1}{\beta} \leq \max\{\frac{f(k)}{k} : k > 0\}$.
  - $\frac{f(k_I)}{k_I} > \frac{1}{\beta}$.
  - There exists a feasible (i.e. less than $\widehat{R}$) extraction level $\widetilde{R}$ which, if performed in one go and used to accumulate capital, leads the country to the concave part of its technology (i.e. if k_0' satisfies $f(k_0') = \phi(\widetilde{R})$, then $k_0' > k_I$).
  - $\widetilde{R}$ is small ($\frac{\phi'(0)}{\phi'(\widetilde{R})} < f'(0)$), which means that k_I is relatively small.
- Then the optimal sequence $k_t^* \longrightarrow k^s$ as $t \longrightarrow +\infty$.
- The natural resource can be a curse (Rodriguez and Sachs 1999): the economy may optimally overshoot its steady state, and then has, during the convergence, decreasing k and c and a negative growth rate.

Intermediate technology relatively to discounting (2)

- Assumptions:
  - $f'(0) \leq \frac{1}{\beta} \leq \max\{\frac{f(k)}{k} : k > 0\}$.
  - $\frac{f(k_I)}{k_I} > \frac{1}{\beta}$.
  - $\widetilde{R} < \widehat{R}$ and $\phi(\widetilde{R}) > f(k_I)$.
  - $f(k_s) + f(k_I) < k^s$, with k_s and k^s satisfying $k_s < k^s$ and $f'(k_s) = f'(k^s) = \frac{1}{\beta}$.
  - $\frac{\phi'(0)}{\phi'(k_I)} < \min\{f'(k^c), \frac{1}{\beta}\}$.
  - $k_0 = 0$.
- Then If the initial stock of resource $\overline{S}$ is large enough, the optimal sequence $k_t^* \longrightarrow k^s$ as $t \longrightarrow +\infty$,
- and if it is small enough $k_t^* \longrightarrow 0$ as $t \longrightarrow +\infty$.

Extension

- Country able to invest in international capital markets, or borrow against its resource stock.
- Debt constraint all the tighter since the resource stock is small.
- Framework particularly relevant for oil-exporting countries.
- Our model can easily embed this case.

- m_t net good imports
- $D_t \gtreqless 0$ net foreign lending or debt
- r world interest rate, exogenous and constant
- Final good domestic market and foreign market balances:

$$\begin{aligned} c_t + k_{t+1} &= f(k_t) + m_t \\ D_{t+1} + m_t &= (1+r)D_t + \phi(R_t). \end{aligned}$$

- $W_t = k_t + D_t$ total wealth
- Resource constraint:

$$c_t + k_{t+1} + D_{t+1} = \max_{k_t \geq 0, D_t \geq \chi(\overline{S})} \{f(k_t) + (1+r)D_t : k_t + D_t = W_t\} + \phi$$

i.e.

$$\begin{aligned} c_t + W_{t+1} &= \max_{k_t \geq 0} \{f(k_t) - (1+r)k_t\} + (1+r)W_t + \phi(R_t) \\ &= \Psi(W_t) + \phi(R_t) \qquad \text{with } W_t \geq \chi(\overline{S}), \end{aligned}$$

where $\chi(\overline{S})$ is the debt constraint, depending on the initial resource stock and non-positive.

- Illustration: case of a technology satisfying $f'(0) < 1 + r$ and $f'(k_I) > 1 + r$. Extending the reasoning to other convex-concave technologies straigthforward.
- Then $\max_{k_t \geq 0} \{f(k_t) - (1+r)k_t\}$ admits a unique solution $\overline{k} > k_I$, satisfying $f'(\overline{k}) = 1 + r$.
- Define $\widetilde{k}_1$ and $\widetilde{k}_2$ by

$$\begin{aligned} f(\widetilde{k}_1) &= (1+r)\widetilde{k}_1 \\ f(\widetilde{k}_2) &= (1+r)\widetilde{k}_2 \\ 0 &< \widetilde{k}_1 < \overline{k} < \widetilde{k}_2. \end{aligned}$$

- Then the extended technology Ψ is:

$$\begin{aligned} \Psi(W) &= (1+r)W, \qquad 0 \leq W \leq \widetilde{k}_1 \\ \Psi(W) &= f(W), \qquad \widetilde{k}_1 \leq W \leq \overline{k} \\ \Psi(W) &= f(\overline{k}) + (1+r)W, \qquad \overline{k} \leq W. \end{aligned}$$