Natural Resources in the Theory of Production

Georgescu-Roegen/Daly versus Solow/Stiglitz

Quentin Couix
quentin.couix@univ-paris1.fr

Université Paris 1 Panthéon-Sorbonne
Centre d'économie de la Sorbonne

4^{th} Science and Energy Seminar
École de Physique des Houches
March 5^{th} 2018

Introduction

- History and epistemology of economics on natural resources
- Controversy between natural resources economics and ecological economics since the 1970s
- Solow, Stiglitz and the theory of growth with exhautible resources
- Georgescu-Roegen, Daly and thermodynamic constraints on production
- A theoretical and methodological perspective

Content

Content

Growth models with exhaustible resources

Robert Solow's address to the American Economic Association in December 1973:

"About a year ago, having seen several of those respectable committee reports on the advancing scarcity of materials in the United States and the world, and having, like everyone else, been suckered into reading *The Limits to Growth*, **I decided I ought to find out what economic theory has to say about the problems connected with exhaustible resources**." (Solow, 1974a, p. 1-2)

Growth models with exhaustible resources

- Robert Solow, "Intergenerational Equity and Exhaustible Resources", 1974; Joseph Stiglitz, "Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths", 1974.
- Production function: $Q = F(K, R, L)$
- Finite stock of resources: $\int_0^\infty R(t)dt \leq S_0$
- Is constant consumption per head across generations possible?

Unbounded resources productivity

"For the problem to be interesting and substantial, R must enter in a certain way. For example, if production is possible without natural resources, then they introduce no new element. [...] On the other hand, if the average product of resources is bounded, then only a finite amount of output can ever be produced from the finite pool of resources; and the only level of aggregate consumption maintainable for infinite time is zero.
The interesting case is one in which $R = 0$ entails $Q = 0$, but the average product of R has no upper bound." (Solow, 1974b, p.34)

Unbounded resources productivity

- Solow: constant population, no technical progress and Cobb-Douglas production function $Q = K^{\alpha} R^{\beta} L^{\gamma}$
- Substitutability of capital to resources: $\frac{Q}{R}$ can grow indefinitely provided K is large enough.
- Stiglitz: growing population, technical progress and $Q = e^{\lambda t} K^{\alpha} R^{\beta} L^{\gamma}$
- Technical progress: variation independent of the factors of production
- Constant consumption is possible under certain conditions

Model-based methodology

"The fact that there is a limited amount of natural resources and natural resources are necessary for production does not necessarily imply that the economy must eventually stagnate and then decline. **Two offsetting forces have been identified: technical change and capital accumulation.**"(Stiglitz, 1974, p. 130-131)

Model-based methodology

- Conceptual shortcomings at the “real world” level:
  - Substitution between natural resources
  - Less resource-intensive goods in the composition of output
  - Fuel saving technologies and technical progress
- The model precedes and gives rise to the concepts

Content

Thermodynamics and natural resources

- *The Entropy Law and The Economic Process* (1971): "**The conclusion is that, from the purely physical viewpoint, the economic process is entropic**: it neither creates nor consumes matter or energy, but only transforms low into high entropy." (Georgescu-Roegen, 1971, p. 281)
- "Energy and Economic Myths" (1975): "Even if technology continues to progress, it will not necessarily exceed any limit [...]. **In the case of technology this limit is set by [Carnot's] theoretical coefficient of efficiency**." (Georgescu-Roegen, 1975, p. 362)
- Sadi Carnot and the maximum efficiency of thermal engines

Georgescu-Roegen's criticism of natural resources economics

- "Comments on the Papers by Daly and Stiglitz" (1979):
  - An incomplete argument: "if [$K \to \infty$], then R will rapidly be exhausted by the production of capital"
  - Logically founded on thermodynamic limits: "the same service can be provided by a design that requires less matter or energy[, but] even in this direction there exists a limit"

Interdisciplinary consistency

- Consistency with existing knowledge from other disciplines
- Problems with the interpretation of thermodynamics: Carnot's coefficient and the efficiency of energy extraction
- Conceptual translation: Carnot's coefficient and limits to the productivity of resources, from thermodynamics to economics

Content

Daly's interpretation of Georgescu-Roegen

- "Georgescu-Roegen versus Solow/Stiglitz" (1997)
- Daly's interpretation:
  "The Solow-Stiglitz [production function] variant includes resources explicitly, but implicitly makes a similar assumption about near perfect substitution of capital for resources — what Georgescu-Roegen aptly dismissed as a 'conjuring trick'. [...] **The conjuring trick is to give the appearance of respecting the first law of thermodynamics (material balance) without really doing so.**" (Daly, 1997, p. 263)
- Conservation of mass or Carnot's maximum efficiency?

The production function and the productivity of resources

- The production function: existing state of the art or improved state of the art?
- Production measure: physical or value units?
  - "even production functions that yield services are producing a physical output" (Daly, 1997, p. 264)
  - "output is measured not in physical units, but in the value of the services associated with it" (Stiglitz, 1997, p. 269)
- Natural resources, non-material services and value

Conclusion

- Theoretical and methodological characteristics
- Conceptual issues lasting over time
- The roots of the opposition between weak and strong sustainability
- An indirect link with energy transition analysis
- The theory of production under the light of natural resources

Thank you for your attention

Quentin Couix
quentin.couix@univ-paris1.fr

References

Daly, H. E. (1997). Georgescu-Roegen versus Solow/Stiglitz. *Ecological Economics*, 22(3):261–266.

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*. Harvard University Press, Cambridge (Mass.).

Georgescu-Roegen, N. (1975). Energy and Economic Myths. *Southern Economic Journal*, 41(3):347–381.

Solow, R. M. (1974a). The Economics of Resources or the Resources of Economics. *The American Economic Review*, 64(2):1–14.

Solow, R. M. (1974b). Intergenerational Equity and Exhaustible Resources. *The Review of Economic Studies*, 41:29–45.

Stiglitz, J. E. (1974). Growth with Exhaustible Natural Resources: The Competitive Economy. *The Review of Economic Studies*, 41:139–152.

Stiglitz, J. E. (1997). Georgescu-Roegen versus Solow/Stiglitz. *Ecological Economics*, 22(3):269–270.