THE ECONOMICS OF ECOLOGY AND CIRCULATION FOR COEXISTANCE BETWEEN HUMANITY AND NATURE

Katsuya Fukuoka
Rissho University, Japan

Keywords: Renewable Resources, Nonrenewable Resources, Industrial Wastes, Household Wastes, Environmental and Social Welfare, Sustainable Management, Natural Resources.

Contents

Summary

Nature is a circulating and open system. It is obvious that if humanity loses the balance with nature, the impact will be not only on humanity but also on others. Humankind should pay attention to external effects, visible and invisible, of the system of nature. We should not forget the basic fact that fundamental goods of existence belong to nature itself, which we utilize without paying the cost as if they are free goods.

Since the Industrial Revolution, we have succeeded in raising the standard of material living by developing natural science, accumulating know-how, and transforming these achievements into technological innovations. The prosperity, however, has been built upon sacrificing the ecosystem, because our goals were the growth of the economic system and maximum profit. We have reached the point where the materials and energy (throughput) which the economic system has taken from ecosystem (natural capacity of purification, including recycling capacity, etc.). Ecology has given warnings to us in this regard.

Therefore, we should create a new economic system in order to achieve coexistence between eternal existence of humanity and other living existence. The new economic system should be based on the principle of coordination and adjustment between economic system and ecosystem. Environmental degradation in the twenty-first century cannot be prevented without addressing this fundamental point. We should change our way of seeing nature as just inputs for our economic activities. More importantly, the economic process of nature has essential functions to sustain lives. We should recognize not only use of resources as marketable goods but also environmental benefits (environmental goods) which we utilize free of charge like goods.

Previously, we did not have this recognition and simply exploited the ecosystem, treating it as an economic process. Now, we should consider the throughput value of the ecosystem, centering on natural processes as potentials that have multiple functions in terms of circulation and movement of materials and energy. Urgent analysis of the relationship between the economic system and ecosystem is undoubtedly required.

1. Introduction

1.1 Global Environment Heading Toward Destruction

The human population of the Earth is currently increasing at an annual rate of 100 million, and the annual loss of forests, as a result of cutting trees for timber and fuel, is 11.3–20.0 million hectares (or about 0.44 km^2 per minute). This and other afflictions, such as desertification of over 5 million hectares, the drying up of water resources equal to hundreds of millions of tons, depletion of oxygen by amounts that can sustain 200–300 million people, and reduction (by hundreds of millions of tons) of the capacity to absorb carbon dioxide, have endangered the Earth's very viability

Desertification alone causes food losses amounting to over US$ 15.6 billion (equivalent to an amount that can support some 15 million people in developed countries). If this continues to increase yearly, it will be equivalent to the total food consumption in Japan over a ten-year period. A continuous population increase of some 1.4 to1.6 times the present 5 to 7 billion is expected to reduce the per capita area of arable land to between 0.15 and 0.3 hectares in the twenty-first century.

Destruction has also reached into the natural environment. For example, long and improper use of large amounts of agricultural chemicals for pest control has resulted in accumulation of toxic material in humans and animals with the resultant potential for incurable diseases. It is further thought that these substances have begun to erode even the functions of the ecosystem itself, as their concentrations have reached levels that ecological processes are unable to handle.

On top of the urgent need for action taken to prevent hunger and disease, there is also an urgent need to control pollution from industry and private households. Chlorofluorocarbon (freon) is used as a refrigerant, in the electronics industry, and as a solvent that is chemically stable and economically advantageous. It is also used to propel gas from hair spray, pesticide, and other such cylinders. It has been recognized, however, that CFCs in the atmosphere cause depletion of the ozone layer, most notably above the Arctic and the Antarctic. It is feared that continued depletion of atmospheric ozone will increase levels of carcinogenic ultraviolet solar radiation falling on the Earth's surface.

Global warming is another concern. Warming is caused by increased atmospheric concentrations of carbon dioxide, methane (resulting, from water pollution and increased numbers of cattle) and chlorofluorocarbons. To reduce concentrations of carbon dioxide, it is vital that all countries reduce their combustion of fossil fuels.

1.2 The Theory of Economy which Preserves Global Environment

The fundamental material circulation system is the basis of all economic activities. Nature is a circulating and open system. It is obvious that if humans destroy the balance with nature, the impact will be not only on humanity, but on all forms of life. Humanity should pay attention to the external effects, visible and invisible, of the natural system. We should not forget the basic fact that the fundamental goods of existence belong to nature itself and we utilize them without paying the costs, as if they were free goods.

Since the Industrial Revolution, we have succeeded in raising the standard of living in the developed world by developing natural science, accumulating know-how and transforming this knowledge into technological innovation. Modern prosperity, however, has been built upon sacrifices of the Earth's ecosystem, because our goal was maximum growth of the economic system and the maximization of profit. We have reached the point where the throughput of materials and energy (which the economic system has taken from the ecosystem) has exceed the buffering capacity of the ecosystem (the natural capacity of purification and recycling, etc.). Ecology has given warnings to us in this regard.

Therefore, we should create a new economic system in order to achieve eternal existence of humanity and other living forms of life. The new economic system should be based on the principle of coordination and adjustment between economic system and ecosystem. Environmental degradation in the twenty-first century cannot be prevented without addressing this fundamental point. We must change our view of nature as merely a source of inputs for our economic activities. More importantly, the economic value of nature and its essential function in sustaining life, must be fully recognized. We must value not only the marketable goods but also the environmental benefits which we currently utilize free of charge.

INPUT	OUTPUT
Production	
Z I_R I_r $R-V-Z$ V	G W'_p
Treatment of industrial wastes	
W'_p	N_p I_r $W_p - N_p$
Consumption	
G G_R	W''_c
Treatment of household wastes	
W''_c	W'_c G_R H_c
Public treatment	
W'_c	N'_p H_g $W_c - N'_p$
Recycle industries	
H_c H_g	N''_p I_r $W_r - N''_p$
TOTAL	
R	W_p W_c W_r

- Z : input of renewable resources
- V : input of non-renewable resources
- N_p, N'_p , N''_p : purification capacity of nature

Figure. 1. Material circulation model

We should consider the throughput value of the ecosystem as potentials that have multiple functions in circulation and movement of materials and energy. There is an urgent need to analyze the relationship between economic system and the natural environment and to recreate the economic system. The model of circulation caused by economic activities and the global environment calculation (material circulation calculation) are shown in Figures 1 and 2 respectively.

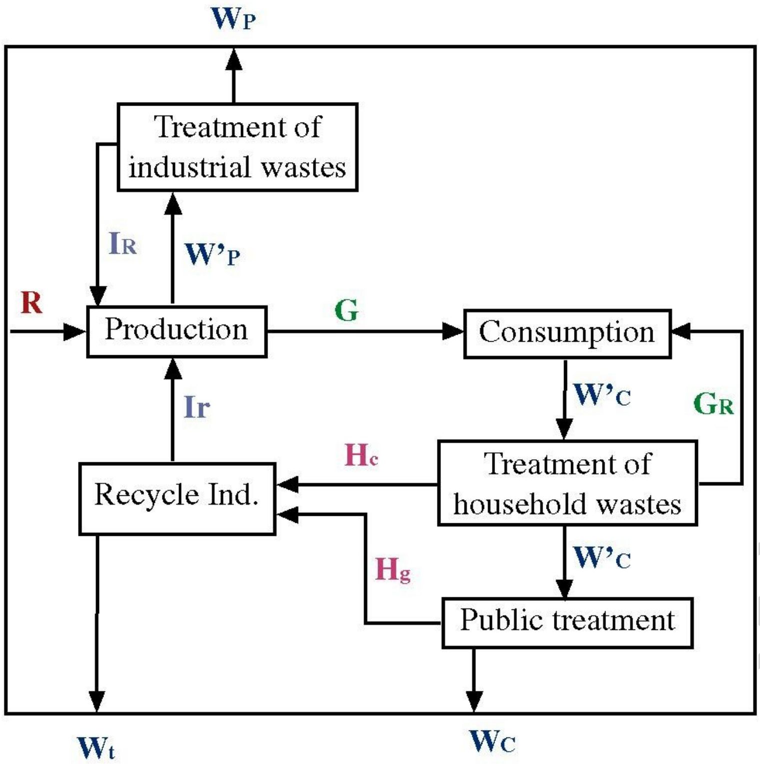

Figure. 2. Material account production

2. Classification of Resources

2.1 Renewable Resources

In the material circulation model, the following two cases should be considered ecologically when economic resources are collected. In case of collecting renewable resources as economic resources, the guiding rule should be not to extract economic resources beyond nature's capacity for renewal. When resources are collected within this capacity, the potential for renewal increases. It can be called the increase in stock or the increase of supply capacity stemming from stock. In this case, there is a possibility that the annual increase of the renewable resource, R, will create increasing levels of profit.

These increases in potential have positive stock effects for global assets. By reducing future profits to current values, balanced utilization of R can be promoted, resulting in stock increase of the global assets. When the prevailing situation is on the brink of collapse, with lowered regenerative power, the immediate goal is to restore regenerative power to the normal level. If the normal regenerative potential cannot be restored, a long-term restoration program is needed. It is crucial not to allow the current situation to degrade any further. Maintenance of the current stock and its regenerative power is a necessary prerequisite for sustainable development.

The minimal marginal principle for extraction should be equilibrium between regenerative power and extraction. And the principle of normal economic activities should be maintenance of global assets. When the rate of extraction exceeds the natural regenerative capacity, ecological balance cannot be maintained without restoration measures. Here, we have an issue of paying cost for erosion of global assets. Loss or the damage to renewable resources can be evaluated by lost environmental benefits, market value or cost for renewal (or exchange). At the very least, the cost to regenerate resources should be invested as a minimum compensation measure.

2.2 Nonrenewable Resources

On the other hand, in the case of nonrenewable resources, the resources just decrease. In this case, therefore, compensation for regeneration is impossible. However, the lost value of resources, when extracted or carried out, can be calculated objectively. By using this lost assets value as criteria, redemption for loss can be prepared. A reserve fund for technological preparations can be appropriated with this redemption fund. Appropriation of redemption for loss of resources is possible, as compensation for future resources. Therefore, when resources are extracted, in addition to the costs of extraction, compensation for regeneration or compensation for erosion is indispensable to deal with the impacts on resources.

3. Classification of Wastes

3.1 Industrial Wastes

In the material circulation model, costs of treatment of industrial wastes are divided into two: one is the cost of treatment of final-stage industrial wastes, another is the costs for recycling reusable resources among industrial wastes. The sum of these two groups of cost should be the minimum share of expenses. Furthermore, when pollution takes place beyond the purification capacity of nature, the amount equivalent to the negative burden on the environment should be paid, as the social cost of pollution. Or, the cost of prevention and removal of pollution must be found. In such cases, these amounts should be paid as social expenses. In the manufacturing sector, in addition to the cost of production, the cost for treatment of industrial waste or the amount of damage to the environment should be recognized as a social expense.

3.2 Household Wastes

The consumption sector receives products from the manufacturing sector and consumes these products as necessary, then discharges them to the household wastes disposal process. Some go to the public waste treatment sector, while others go to the recycling industry sector as reusable resources. In the public waste treatment sector, some are discharged out of the economic system as final-stage general wastes and others go to the recycling industry sector as reusable resources, after treatment.

The cost of waste treatment within the household is paid by the household. The recycling cost, such as cost for separation of wastes, can be offset by returned money (such as deposits) from the recycling industry. So, the cost of waste treatment less the returned money is the real share of the household, when the returned money falls short of the recycling cost.

When wastes are treated directly by the household, the household provides the labor for treatment. On the other hand, when households discharge their waste to public waste sectors, local governments or other public waste treatment sectors pay the costs of waste treatment or recycling. The usual situation is that these costs are shared by public waste treatment sectors and local government.

However, when discharge of general waste from households exceeds the purification capacity of nature, the amount equivalent to the burden on the environment for the excess should be paid as a social cost. This system is not yet well established.

Reusable resources coming from the consumption sector through household or public waste treatment sector can be transformed into inputs for the production sector, by re-processing. Needless to say, costs arise for this transformation. And here, again, some nonreusable resources are discharged outside the economic system. If these discharges exceed the purification capacity of nature, the amount equivalent to the burden on the environment caused by the excess should be calculated as social costs.

4. Maximization of Environmental and Social Welfare

4.1 Environmental Benefits

There are environmental benefits that are offered not through the market, but as free goods. These environmental benefits are provided directly as material goods to production, consumption, waste treatment, recycling and public waste treatment and other sectors. These benefits are currently neglected in the market economy as goods without share of cost. In reality, however, benefits from nature (environmental benefits or environmental goods) exist at all levels of production, consumption, waste treatment and recycling in the material circulation system, in addition to substances which are extracted and circulated for use as marketable goods or public goods. Strictly speaking, these environmental benefits belong to the material circulation process and to economic activities.

4.2 Maximum of Social Welfare

These benefits from nature are treated as noneconomic goods because they are free goods without share of cost and they exist outside the market process. But they are indispensable circulating materials that cannot be ignored in the real material circulation. So, the fundamental circulation system should include these benefits from nature.

From this perspective, current economic activities based on GNP is insufficient to maximize socia1 welfare. Efforts should be made to minimize various environmental effects that are imposed on the ecosystem by the economic system. The maximum of social effects can be achieved only when marginal effects are adjusted and balanced corresponding to the total amount of various private marginal production cost, marginal waste treatment cost, marginal pollution prevention and removal cost, marginal resources compensation cost, marginal resources regeneration cost, and marginal pollution compensation cost. In doing so, the share of various environmental costs outside the economic system can be calculated rationally as well as necessarily. They include costs for waste treatment, costs for prevention of pollution caused by waste treatment, costs for venous process such as recycling costs for compensation of environmental contamination caused by excess of the purification capacity of nature, compensation cost to restore regenerative power of nature when regenerative power of nature are exceeded by resource extraction and costs to maintain regenerative power of nature indefinitely.

4.3 Fundamental Theory of Environmental Economics

If we suppose that the value of ecological assets at the initial year is Vo, the value of ecological assets at the year T is V(T), the annual interest rate is r, and the total current value of positive effects, including environmental preservation effects, stemming from monetary investments by the year T, which in the last year of the environmental preservation program period is U, the equilibrium condition to realize its maximization in the period of T years can be calculated as follows.

Here, the amount of added value as traditional welfare criteria is E(t), the amount of environmental benefits as criteria to be newly added is B(t), the corresponding economic cost is C(t) and the sum of various cost for environmental preservation is Ce(t)

$$\begin{aligned} U &= \int_0^T [E(t)+B(t)]e^{-rt}\cdot dt + V(T)e^{-rt} - \int_0^T [C(t)+Ce(t)]e^{-rt}\cdot dt - V_0 \\ &= \int_0^T [E(t)+B(t)-C(t)-Ce(t)]e^{-rt}\cdot dt + V(T)e^{-rt} - V_0 \end{aligned} \tag{1}$$

$$\frac{dU}{dT} = [E(T)+B(T)-C(T)-Ce(T)]e^{-rT} - rV(T)e^{-rT} + V'(T)e^{-rT} = 0 \tag{2}$$

$$U = \left[\int_0^T \{E(t)+B(t)-C(t)-Ce(t)\}e^{-rt}\cdot dt + V(T)e^{-rT} - V_0\right]\times\frac{1}{1-e^{-rT}} \tag{3}$$

$$\begin{aligned} &[E(T)+B(T)-C(T)-Ce(T)] = rV(T) - V'(T) + \frac{r}{1-e^{-rT}} \\ &\times\left[\int_0^r \{E(t)+B(t)-C(t)-Ce(t)\}e^{-rt}\cdot dt - V_0 + V(T)e^{-rT}\right] \end{aligned} \tag{4}$$

To maximize new social welfare, ecological assets should be maintained sustainably in terms of ecology. At least, we should not degrade ecological assets that we preserve and utilize today and we should activate, preserve and pass on these ecological assets at the same level as in the past, or higher.

Also, we should maintain ecological assets and preserve them for eternity. We should not deprive ecological assets of resources but we should make sacrifices to maintain and repair assets for harvesting of resources. The issue of maintenance of global assets as substance is the challenge of the twenty-first century that confronts humanity.

-
-
-

Bibliography

The Fundamental Theory of Environmental Economics

Boumol W. J. and Oates W. E. (1988). *The Theory of Environmental Policy*, pp. 7–109, 177–256. Cambridge: Cambridge University Press. [This presents the theory of externalities and the design of environmental policies.]

Fukuoka K. (1975) *Human Environmental Economics*, pp. 3–44, 217-227. Ochanomizushobo. [This provides the fundamental theories of human environmental problems in urban area.]

Fukuoka K. (1998). *Ecological Economics*. Tokyo: Yūhikaku Press. pp. 1–10, 24–33, 75–91. [This provides the management of regional ecosystem for environmental conservation.]

Fukuoka K. (2000). *The Fundamental Theory of Eco-economics*. Tokyo: Chikusha Press. pp. 119–147, 159–175, 220–228. [This provides the application of economic theories to the equilibrium of environmental market and public policies.]

Mäler K. G. (1971). *Environmental Economics*. Baltimore, MD: Johns Hopkins University Press. pp. 19–57, 158. [This provides the theoretical approach to the equilibrium model of environmental quality.]

Nijkamp P. (1977). *Theory and Application of Environmental Economics*. Amsterdam: North-Holland. pp. 41–62, 95–226. [This presents the economic-ecological models and programming models for environmental quality analysis.]

O’Connell J. F. (1978). *Welfare Economic Theory*. pp. 73–99. [This presents the basic theory of social welfare criteria and social evaluation.]

Seneca J. J. and Tanssig M. K. (1978). *Environmental Economics*. [This presents the background to environmental economics and market problems.]

Whitcomb D. K. (1972). *Externalities and Welfare*. New York and London: Columbia University Press. pp. 83–135. [This provides the theory of externalities and the social welfare.]

Environmental Problems and Policies

Fukuoka K. (1983). Forest education as a branch of environmental education. *Review of Forestry Culture*, **4**(1), 107–112. [This presents the system and subject of environmental and natural education.]

Fukuoka K. (1984). The economic signification of forestry culture. *Review of Forestry Culture*, **5**(1), 1–8. [This presents the characteristics of Japanese traditional communities in the case of communal forests.]

Fukuoka, K. (1990). *The Structure of Destruction of the Earth*. Tokyo: Jiji Newspaper Press. pp. 21–101, 134–156. [This presents the application of the ecological theory to economical behavior.]

Fukuoka K. (1993). *The Strategy of Conservation for Earth Environment*. Tokyo: Yūhikaku Press. pp. 153–178, 183–226, 237–268. [This provides the history of global policies and the coordination of international conflicts on environmental policies.]

Nijkamp P. (1976). Spatial Mobility and Settlement Patterns: An Application of a Behavioural Entropy. *Research Memorandum RM-76-45*, International Institute for Applied Systems Analysis, Luxemburg. pp. 1–3. [This provides the structure of destruction of natural environment and evaluation of environmental costs.]

Evaluation of Environment

Burt O. R. and Brewer D. (1971). Estimation of net social benefits from outdoor recreation. *Econometrica*, **39**(5), 813–826. [This presents the evaluation method of economical effects of recreation.]

Cicchetti C. J. and Smith V. K. (1976). *The Costs of Congestion: "An Econometric Analysis of Wilderness Recreation"*. New York: Ballinger Publishing Co. [This presents the application of econometrics to the evaluation of natural recreation.]

Fukuoka K. (1981). Environmental evaluation and economical value of forests. *Review of Forestry Culture*, **2**(1), 7–15. [This provides the results of real evaluation of forest-ecosystem in various kinds of public benefits.]

Fukuoka K. (1982). The multiple effects of investment for the conservation of forest environment. *Review of Forestry Culture*, **3**(1), 33–42. [This presents the applications of multi-criteria analysis to natural resources.]

Fukuoka K. (1983). Optimal control for forest and water evaluation of public benefits. *Review of Forest Culture*, **4**(1), 37–42. [This presents the results of researches to Japanese rivers and mountains by the model of dynamics.]

Hansen N. M. (1975). An evaluation of growth center theory and practice. *Environment and Planning*, **7**, 821–831. [This presents empirical examination of economic-ecologic linkages and willingness to pay for environmental goods.]

Johonsson P. O. (1983). Disequilibrium cost-benefit rules for natural resources. *Resources and Energy*, **6**, 355–372. [This presents the special problems in the case of application of cost-benefit rules.]

Johonsson P. O. and Löfgren K. G. (1996). *The Economics of Forestry and Natural* resources. Oxford: Basil Blackwell. pp. 46–72, 205–217.

Mishan E. J. (1972). *Elements of Cost-Benefit Analysis*. London: George Allen and Unwin. Pp. 25–111. [This provides the basic theory of cost-benefit rules and evaluation practice.]

Waller, R. A. (1974). The assessment of environmental standards. In J. T. Coppock and C. B. Wilson, eds. *Environmental Quality*. Edinburgh: Scottish Academic Press. pp. 90–108. [This presents the structure of environmental evaluation of external impact and determination of environmental standards.]

Ecological Management and Planning

Berry B. J. L and Horton F. E. (1974). *Urban Environmental Management*. Englewood Cliffs, NJ: Prentice-Hall. pp. 15–24. [This provides the fundamental theory of urban environmental management and the direction of urban development.]

Fukuoka K. (1980). Environmental planning of forests. *Review of Forestry Culture*, **1**(1), 15–22. [This presents the outlook of Japanese governmental forest policy and systems.]

Johansson P. O. and Löfgren K. G. (1985*). The Economics of Forestry and Natural Resources*. pp. 22–72. [This provides the theory of renewable resources, the optimal rotation period and the optimal pricing of natural resources.]

Kalemperer W. D. (1996). *Forest Resource Economics and Finance*. New York: McGraw-Hill. pp. 448–496. [This provides the environmental conservation method of rural areas and practical problems of rural development.]

Lyon K. S. and Sedjo R. A. (1983). An optimal control theory model to estimate the regional long-term supply of timber. *Forest Science*, 29, 798–812. [This presents the sustainable theories and policies to the forest management.]

Perloff H. S., ed. (1969). *The Quality of the Urban Environment: Resources for the Future*. Washington, DC. [This provides the environmental conservation method of urban areas and practical problems of urban development.]

Biographical Sketch

Katsuya Fukuoka, born 18 May 1930 in Japan, received his education from the Department of

Agriculture and Forest Science, University of Tokyo, taking a Ph.D. in Evaluation of Forest Resources and Accounting Systems of Forest Management. He has taught at the University of Yamagata (1966–1972), the Metropolitan University of Tokyo (1973–1989), the University of Tokyo (1978–1990), the University of Nagoya (1981–2000), Rissho University (1972–2001), and Waseda University (1998–2001). In addition, he has served as the Dean of Faculty of Economics (1989–2000), and Chairman of the Committee of Postgraduate Economics, Rissho University (1989–2000). He has been appointed to the Committee Staff of Development of Water Resources to the Minister of Management of Land (1987–1999); to the Committee Staff of Earth Environmental Research (Japan Science Council, 1994–2000); to the Special Committee Staff to the Minister of Science and Technology (1991–1992); to the Committee Staff of Food Problems to the Prime Minister (1995–1996); to the Committee Staff of Environmental Support to the Developing Countries to the Minister of Environmental Affairs; and to the Committee Staff for Evaluation of Technology to the Minister of Agriculture, Forestry and Fishery (1996–2001). He has also been elected as the President of the Japanese Regional Science Association (1998–2000), and as President of the Foundation for Earth Environment (1996–).