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Externalities and Growth *

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In a recent paper in this Review, Ayres and Kneese [1] make a fundamentally important contribution to economic theory. It is the purpose of this note to point out several implications of their analysis which I think deserve particular emphasis.

Ayres and Kneese make, among others, the following points: (1) Because of the physical laws governing the conservation of matter and energy, the amount of "waste" given off by economic activity must equal the physical quantity of primary inputs. (2) Final "consumption" is a flow of services from the tranformation of materials, and is not the physical disappearance of materials. (3) The physical output of economic activity, net of inventory accumulation, is waste and must reenter the environment. But the environment itself is both a consumption good and a source of primary inputs. Disposal of waste into the environment thus affects the relative scarcities of various goods, and hence their implicit prices. (4) Since these effects do not in general have explicit prices, they are externalities; they are not accounted for by the private market. As a result, the price system does not lead to a Pareto-efficient allocation of goods and services. (5) The extent of the distortion of

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allocative efficiency from this source is growing, both because the effects of waste disposal are cumulative, and because the flow of waste is necessarily proportional to the flow of economic output, which is increasing in a growing economy.

Although Ayres and Kneese speak of the "waste assimilative capacity" of the environment, I think this is slightly misleading. The tranformation of primary inputs (minerals, soil, air, sunlight, etc.,) into waste must necessarily alter the environment. No doubt some of the waste has the same form as the original inputs, but in general this can not be the case. The industrial economic system of mankind is like a cancer in world ecology. It grows "out of control" of the ecology itself.

The extent of the allocative distortion and cost caused by the externality effect of waste grows in time in three ways. Two of these ways are are summarized in point (5) above; the third is illustrated in the following model, and derives from the public good aspect of external effects.

Suppose that Y is aggregate output (in the economic sense) and that n is population. Then if y is per capita income or output,

(1) $Y = yn.$

The flow of waste is equal to the flow of output, in physical terms. If e is a dimensionality constant, then the physical flow of waste externality is

(2) $E = eyn.$

The external effect of a flow of waste into the environment is usually associated with a density effect. That is, the cost of the externality is proportional to the cumulative density of waste. This is illustrated by DDT. Other waste flows may be partly "assimilated", as when carbon dioxide is absorbed by plants. But in this case there may still be a net excess flow which accumulates. If the environment is treated as a fixed stock with respect to the net flow (unassimilated) of waste, then the density is

(3) $$D = D(eynt),$$

where t is time. Even though Y remains constant, accumulation results in increasing density through time. Equation (3), in which D is a monotonic increasing function of yn and t thus illustrates the two ways in which externalities increase in Ayres and Kneese's formalation. But there is a third way in which the cost of the external effects may increase. Suppose that the waste accumulation is an economic bad detracting from the utility of the environment as a consumption good and a producers' good. Let the cost of waste density in the environment be $d per person per unit density. (That is, every person suffers equally from the externality and on average each person would be willing to pay $d to get rid of one unit of waste density.) Letting d be a constant is conservative; it seems more likely that d is an increasing function of D.

The total social cost of the externality is then

(4) $$C = nd\,D(eynt),$$

ignoring indirect allocative costs. If population is growing, then the social cost of the externality grows faster. The public good nature of the externality means that there are economies of scale of suffering with respect to population. To illustrate this, suppose that the following explicit equations describe the system:

$$(5) \qquad D(eynt) = gnyt$$

$$(6) \qquad n(t) = n_o e^{rt}$$

$$(7) \qquad y(t) = y_o e^{bt} .$$

Then total direct social cost at time t is

$$(8) \qquad C(t) = dtgn_o y_o e^{(2r + b)t} .$$

In other words, if population grows at the rate r and percapita income grows at the rate b, then the social cost of economic waste grows at a rate in excess of (2r + b). Similarly, externality cost per capita, c, grows faster than the rate of growth of per capita income:

$$(9) \qquad c = dgt\, y_o\, e^{(r + b)t} .$$

If the physical units are commensurable we can write the <u>proportion</u> of externality lossds in total production:

$$(10) \qquad P = gt\, e^{rt} .$$

Externality cost thus not only grows over time, but it grows faster than the economy giving rise to it. In addition to the direct cost of the externality, there is an economic loss from the resulting distortion of the price system if the externalities are unpriced. Presumably this allocational disruption is proportional to the importance of the externalities in total product. Since it is well-known that the private market can not deal effectively with this problem, the growing cost of waste externalities in a growing economy implies an increasing need for (cost of not having) centralized decision-making.

This is an interesting paradox. A private market system which is successful, in the sense that it generates growth in percapita income and in population, becomes increasingly obsolete. The more it grows, the costlier it becomes to maintain. At some point the enormous savings in information costs which it provides are outgrown by its external costs.

To put the problem in a slightly different perspective, it is often alleged that economies of scale are an important source of economic growth. The Ayres and Kneese analysis suggests that there are increasingly important diseconomies of scale from large industrial economies. Presumably the net scale effects are a decreasing function of the size of an economy. In the early stages the private market mechanism works well (except for social overhead investments), but as the economy progresses centralized decision-making becomes increasingly preferable.

There is another way in which centralized decision-making becomes of increasing importance in a growing economy, and that is through public goods themselves. Public goods and externalities have much in common; for instance their optimality conditions are identical [2]. As with externalities, the private market fails when there are public goods [3]. Public goods can not be provided by competitive private firms. Since the marginal cost per person of a public good (at a given level of quality or intensity) is zero, the price per person would be driven to zero by competition. There are economies of scale with respect to persons in the provision of public goods. In an economy with population growth this may imply that public goods assume an increasingly important role in the optimal consumption bundle. This in turn means an increasing need for centralized decision-making.

These statements can be illustrated by a simple two-good economy. Let

$n(t) = n_o e^{rt}$	be population at time t,
$X(t)$	be per capita output of a private good,
$G(t)$	be per capita and total output of a public good,
$W = X^{\lambda} G^{1-\lambda}$	be a social welfare function of the Cobb-Douglas form, and
$an = (nX + G)^{\theta}$	be a transformation function with one input (labor) and two ouputs, nX and G.

The transformation function has diminishing returns if θ is greater than unity. If the social welfare is maximized with respect to per capita output of each good, then the optimal time path of consumption of each good is given by

$$X(t) = \lambda \, a^{1/\theta} (n_o e^{rt})^{1/\theta - 1}$$

(11)

$$G(t) = (1 - \lambda) \, a^{1/\theta} (n_o e^{rt})^{1/\theta} .$$

Not only does the ratio G/X increase over time at the rate r, but per capita consumption of the private good actually declines. This of course is due to a substitution effect in favor of the public good as its cost declines, per capita, with population growth. The model is over-simplified and extreme, in that no account is made of an income effect which may well operate in the opposite direction. But the point is illustrated.

It is the public good aspect of waste externality which led to the same sort of conclusion above. Mere population growth, at constant levels of per capita income, is sufficient to give rise to these substitution effects, just as population growth alone was a cause of increasing externality cost for a given level of waste density.

Both of these phenomena have implications for distribution. The "commonality" aspects of external effects and public goods imply that consumers increasingly face the same or a similar array of cost and consumption possibilities, whatever their initial endowments. Actually, it may be better to view it as a situation in which initial endowments are much the same. Efforts by individual consumers to compensate for externality costs by increasing consumption give rise to negative aggregation effects, increasing the externalities.

Finally, it is an interesting question worthy of further study, whether technology and innovation are biased in favor of public goods and activities having externalities. The researches of government-supported study groups might well be biased in favor of public solutions if not public goods. A bias in private decisions, including innovative decisions, in favor of externality-producing activities is certainly not hampered by the fact that these externalities are unpriced when diseconomies are involved. The opposite is obviously the case with external economies. Some examples do come to mind. The technology of warfare a hundred years ago was not perhaps so neatly illustrative of a public good as it is today. Electronic mass media and the automobile (with its complements) are other examples of fairly recent goods with important aspects of publicness and externality. And these phenomena are quite aside from the Ayres and Kneese waste externalities which are of the most fundamental importance.

References

[1] R. U. Ayres and A. V. Kneese, "Production, Consumption, and Externalities," American Economic Review, June, 1969.

[2] J. M. Buchanan and W. C. Stubblebine, "Externality," Economica, November, 1962.

[3] P. A. Samuelson, "The Pure Theory of Public Expenditure," R. E. Stat.,November, 1954.