GLOBAL AND REGIONAL IMPLICATIONS OF THE SOCIAL COSTS OF ENVIRONMENTAL POLLUTION

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The theory of social costs depends on the accurate evaluation of production and consumption externalities and their impact on the ecology and economy. In classical theory these externalities occur only when an economic activity causes measurable damage to some segment of the ecology or society.[1] Until very recently the ecology of our earth has shown itself to be exceedingly resilient, capable of absorbing large quantities of man made effluent with little or no apparent ecological or social damage. In our past history the assimilative capacity of the environment has provided free effluent removal for many civilizations through eons of time. Man has accepted this free assimilative capacity of his environment as a gift of nature. This assimilative capacity of the environment has conferred untold consumer and producer surplus on countless individuals and institutions in the economic process. Society's continued undervaluing of the assimilative capacity of the environment has led to the continued overuse of the environment in our productive and consumptive activities. Recently, the overuse of the environment has severely damaged the ecology and in many cases society.

This paper revises the classical theory of social cost to include the productive value of the environment. The first section of the paper reviews the classical theory of social costs. The second section introduces the assimilative capacity of the environment as a measurable externality. In this section the assimilative capacity of the environment is measured as either consumer or producer surplus conferred on the individual or society conducting the polluting economic activity. The paper concludes by suggesting that society should increase its productive activity only up to the point where the revised marginal social costs equal the net marginal benefits of the activity.

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[1]See Coase [2, pp. 1-44], Fisher [3, pp. 1-33], Mishan [5, pp. 1-28].

Classical Theory of Social Costs

The measure of social costs depends on the externalities involved with production or consumption activities. All economic activities result in discharge of effluents into the environment, R_t. These discharges vary in intensity with the type level of economic activity Y_t and length of time involved (t) as indicated by Equation 1. The production of steel, for example, seems to discharge

$$(1) \quad R_t = F(Y_t, t)$$

much more effluent into the environment than the growing of an organic garden. Nevertheless, both activities cause disruption to the existing environment. This disruption is an effluent.

The amount of effluent discharged into the environment depends on the level and type of economic activity. As this activity increases the rate of change in the discharge of effluents, $\partial R/\partial Y$, may fluctuate, but for simplicity it will be assumed that $\partial R/\partial Y$ is constant. In Figure 1-a the discharge of effluents is assumed to be linearly related to the level of activity so that $\partial R/\partial Y = b$ for a given period of time. Thus, as output increases from zero to Y_t the discharge of effluents, R_t, increases from zero to bY_t du ing this time period.

At low levels of economic activity the discharge of effluents is relatively low and the environment has the capacity to assimilate these effluents. The assimilative capacity of the environment essentially neutralized the harmful elements of the effluents transforming some into useful nutrients, diluting or dispersing others during a given period of time.[2] In most cases, the half life of the pollutants is very short. Ashes to ashes and dust to dust seems to take special significance for many effluents in relatively small quantities. For some pollutants the time to neutralize the pollutant is very long thus the assimilative capacity of the environment is very low. The environmental assimilative capacity for time period t is shown in Figure 1-a as EE_t. If the pollutant level is OE or less the environment can cleanse itself of all the harmful elements of the effluent during this time period.[3]

The environmental assimilative capacity of a stream, for example, represents the ability of the stream to transform an effluent into useful nutrients for aquatic life or dilute and transport the more harmful elements to the sea. The stream's assimilative capacity is also influenced by the volume of effluent

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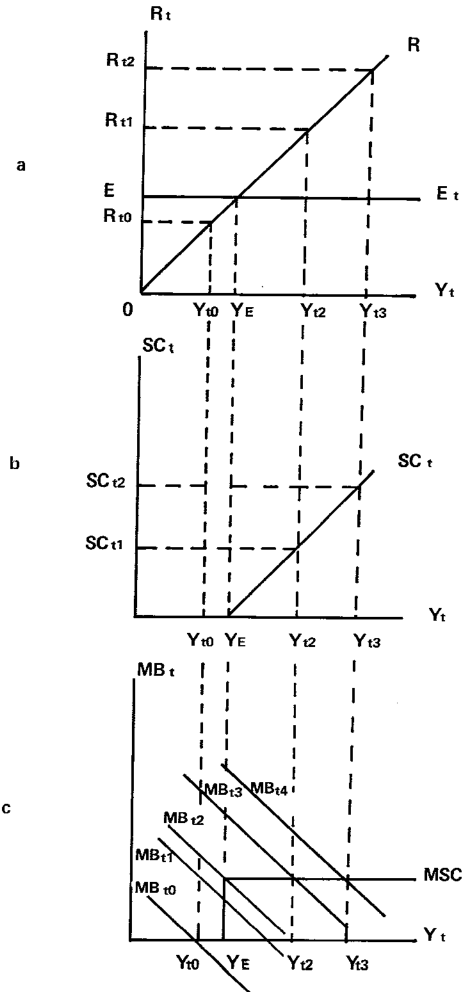
[2]If the environment transforms some pollutants into useful nutrients this transformation yields external benefits to society and the ecology, thus increasing society's net marginal benefits of the activity.

[3]It is assumed that the environmental assimilative capacity may neutralize all pollutants in the same fashion regardless of the combination of pollutants discharged. It is recognized that certain relatively harmless pollutants may in combination cause a very toxic discharge. Also assume $\partial R_t/\partial_t = 0$ for simplicity.

FIGURE 1
Social Costs And Environmental Pollution
For Time Period t



(See Note)

Note: EE is shown to be unaffected by overuse of the environment during time t when in reality it may be reduced dramatically. If EE is reduced SC will shift to the left as a result.

introduced over a particular time period. As long as the discharge of an effluent is small the stream will be able to dissipate, dilute, or transform many pollutants without ecological harm or social damage during this time period.

If the level of output should rise above (Y_E), the level of effluent will rise above OE, the cleansing capacity of the environment for this period of time. In this situation, the effluent will begin to cause ecological and social damage, D. The environment will no longer be able to completely transform or transport the effluent and neutralize it during time period t. The environment is choked with pollution and the ecological balance is disrupted. As the ecology is altered, society may be harmed by disease, material damage, or lost production if the pollution continues into the future.

(2) $D_t = D(R_t - E_t)$

Social costs have been traditionally defined as the economic value of the damages imposed on society by some production or consumption activity.[4] The social costs imposed by increasing an economic activity beyond the assimilative capacity of the environment can be measured as equation 3 where P represents the value per unit of the environmental damage.[5] If $Y_t < Y_E$ then $SC_t = 0$, since $D_t = 0$. However, if output rises above Y_E then $SC_t > 0$ because $D_t > 0$ (see Figure 1-b).

(3) $SC_t = P * D_t$

Assuming that the rate of discharge is a linear function of output, the SC_t function is a linear function with a slope of b. The marginal social cost function, MSC_t is given as $\partial SC/\partial Y = P * \partial R/\partial Y = P * b$ when $R_t > E$. Therefore, MSC_t is a step function shown in Figure 1-c and will be equal either to zero if $Y_t < Y_E$ or $P * b$ if $Y_t > Y_E$.

The regional implications of the traditional measure of social costs are analyzed by introducing Net Marginal Benefits, MB, of the economic activity into Figure 1-c. The regional MB_t represents all private and public benefits of an economic activity less all private costs during time period t. If traditional benefit cost criterion are employed, then the regional society should increase its economic activity as long as $MB_t > MSC_t$. If MB_t exceeds the MSC_t, the society is better off increasing this activity. Once $MB_t = MSC_t$ society has reached the optimum level of output Y_t. If society attempts to expand production beyond this level, society's welfare begins to fall since $MB_t < MSC_t$, and external diseconomies are encountered.

[4]For a discussion of Social Costs see Fisher [3, pp. 19-24] or Coase [2, pp. 1-44].

[5]This value may be measured in terms of the health hazard created or material destruction caused by the discharge.

Of course MB_t may take on any value but at any given point in time the MB_t of any production or consumption activity is believed to be inversely related to Y since the law of diminishing marginal utility is expected to hold. Using this analysis of MB_t, five separate values for MB_t are shown in Figure 1-c, and their effect on pollution investigated. If MB_{to} prevails, society will produce at Y_{to}, but this level of activity will cause only R_{to} discharge. This level of discharge is below the assimilative capacity of the environment, EE; therefore, this level of economic activity leaves society and the environment unharmed. Assuming productive activity generates MB_{t1} society will increase its output to Y_E and the effluents to R_E. Society's welfare will increase as long as $Y_t < Y_E$ since MB > MSC. Once $Y_t = Y_E$ then $MB_t = MSC_t$ and society has maximized its welfare. This level of output fully utilizes the assimilative capacity of the environment but still causes no social or environmental damage. Even if the benefits of production rise to MB_{t2} society will find that output Y_E is the optimum level. Assuming that society pushed Y beyond Y_E the MSC_t of this action would rise above MB_{t2} as the increased production caused damage to rise faster than benefits. Under the first three values of MB, society would find no reason to overload the ecology with effluents in order to generate additional benefits.

As MB rises to MB_{t3} or MB_{t4}, a regional society would find that the level of output Y_{t2} or Y_{t3} would generate so much effluent that the environmental assimilative capacity would be exceeded. The economic activity causes damage to the ecological and possibly social systems. Nevertheless, if MSC is measured accurately, society finds the increase in benefits exceeds the MSC. The rational choice is to push production forward, damaging the ecology and possibly society. The level of damage done by society's productive activity depends on the MB generated by such activity and the MSC caused by the effluent.

Naturally, the choice discussed in the last paragraph is rational only if the SC have been accurately measured. If SC have been underestimated, society's welfare will not be at an optimum level if output is pushed to the levels suggested. Economics is valuable in environmental decisioning only when it accurately measures both benefit and costs, especially Social Costs. Currently, estimates of Social Cost are seriously biased because of the theoretical error in not including the value of the assimilative capabilities of the environment.

A Revised Theory of Social Costs

Although this theoretical defect in SC is serious, the change in theory necessary to correct this defect is minor.[6] Social Cost stems from production or consumption of products and services. As previously stated, as output rises the real discharges into the environment also rise. These discharges include sewage and waterborne waste, smoke and stack emissions and noise, to mention a few. Not all emissions alter the environment; however, if the discharge is large during a given period of time these emissions can cause observable damage

[6] The theoretical defect was first discussed briefly by Peterson [7] but really surfaced in a discussion with referees for Peterson [9].

to the ecology and society. Low levels of production result in small effluent discharges over time. These effluent discharges can be effectively neutralized by the environment but this neutralization reduces the remaining assimilative capacity of the environment for the time period (see equation 4). Society has fewer options available now than it did prior to the discharge because K is smaller. The discharge of this effluent imposes an opportunity cost on society

(4) $K_t = g(E - R_t)$

where:

$E > R_t$ and K_t is the cleansing capacity of the environment

in terms of the lost assimilative capacity of the environment.

If it were not for the assimilative capacity of the environment, producers and consumers would be forced to neutralize all wastes generated by their activities to maintain a healthy environment and society. This neutralization of waste would force consumers and producers to incur real costs to process the waste product of their current activities and properly neutralize or dispose of them. At the current time much of these disposal costs are being avoided since the environment is cleansing itself. Since these activities are avoiding real costs producers and consumers are receiving an unearned surplus generated by the environment. By conferring this surplus on one segment of society, society loses the opportunity of being able to confer this surplus on another segment of society. Thus, giving away the productive assimilative capacities of the environment will cause both economic efficiency and income distributional problems.

By giving away the environment's assimilative capacity, society is attempting to induce polluting industries to locate in their region. If this bribe is successful the industry may locate in this region but this action reduces the economic efficiency of the global society by introducing noneconomic criterion into an economic decision. The regional society will find, moreover, that this strategy is not free because it has a cost, an opportunity cost. Once the assimilative capacity of the region is given away to one or a group of industries society can no longer offer this as an inducement to other industries without damaging the environment and society. This opportunity cost may be used to measure the value of the environmental resource to society. For example, society may find that it may use its atmospheric assimilative capacity either to eliminate smoke pollution of a steel mill or a refinery. Thus, if the steel mill is given the use of the atmosphere, the opportunity cost to the society is the inability to offer the refinery free atmospheric disposal of its pollutants as an inducement to locate in the region. Naturally, if society is willing to bear both ecological and social damage, the region may allow the refinery to locate in the area without pollution control. If they do locate in this manner, society must either suffer the damage or pay to have the pollutants neutralized. In this sense, the value of the atmospheric assimilative capacity could be measured indirectly as the lost opportunity of not being able to attract the refinery.

Unfortunately, the opportunity cost method of evaluating the assimilative capacity of the environment is impractical. This impracticality is obvious.

The number of industries not located in a region is limitless, thus the estimates of the opportunity costs are also limitless.

Society may evaluate the environment's assimilative capacity indirectly by estimating the income distributional disparities introduced when the resource is given away. The practice of giving away the assimilative capacity of the environment causes income distributional problems by providing some, but not all, segments of society with an unearned income increment. This windfall profit creates distributional problems between individuals and industries. The owners of the recipient resources, i.e., capital and labor, earn higher incomes than might ordinarily be expected since their employing firms do not pay the entire cost of production. If only a few steel firms are allowed to discharge effluents into the atmosphere free of charge, these firms will generate higher than normal profits and possibly pay higher wages relative to the industry, other things equal. Therefore society's value of its environmental assimilative capacity may also be measured, theoretically at least, as either the consumer or producer surplus generated by the environment's neutralization of pollutants.[7] In the steel mill example, the steel firm has received an unearned producer surplus measured as the production cost avoided as the result of the environment assimilating its pollutants.

In this situation, the social costs of an effluent is a function of the discharge, R_t, and the value of the lost environmental assimilative capacity measured as either producer or consumer surplus, W. The revised theory measures social costs from the initial discharge of the effluent rather than from the first measurable damage. As output and consumption rise, the effluent

(5) $SC_t = W * R_t$

also increases, $\partial R/\partial Y$. In Figure 2-a, the rate of discharge is assumed to be linear; therefore, $\partial R/\partial Y = b$ and $R_t = bY_t$. As long as $Y_t < YE$, this effluent is neutralized by the environment at no direct cost to the consumer or producer. This cleansing of the environment increases the consumer and producer surplus from productive activity. However, the assimilative capacity of the environment has been reduced. The environment cannot assimilate the same quantities of effluents now as it could before the productive activity began. The consumer or producer surplus is generated at the expense of the environmental assimilative capacity. Therefore, the value of the environmental assimilative capacity may be measured as the value added to either producer surplus or consumer surplus or both.

Again referring to the steel example a small discharge into the air may be diluted by the large volume of clean atmosphere. However, the discharge has reduced the assimilative capacity of the atmosphere for a period of time and reduced the atmosphere's ability to neutralize additional pollutants. The atmosphere essentially provides pollution abatement for the effluent discharged. If raw effluent is discharged into the atmosphere, the institution discharging the effluent is receiving free pollution abatement of its effluent and thereby increasing its producer or consumer surplus from its economic activities. Thus, as long as $Y_t < YE$ the social cost of an environmental

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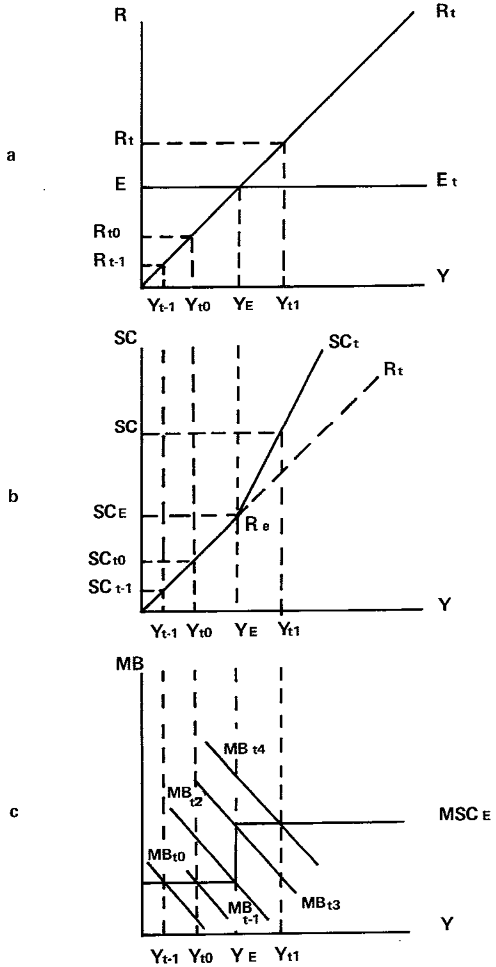
[7]Mishan [4].

FIGURE 2

Social Costs Considering Environmental Cleansing Capacity

Time Period t



discharge is simply the value of the reduced assimilative capacity of the environment suggested by equation 6 and shown as SC_t in Figure 2-b. Naturally, if we can measure the assimilative capacity of the environment, society may wish to sell the development rights to potential users of this capacity. The sale of these rights would measure the producer and consumer surplus directly, giving a market estimate of W.[8]

If the environmental discharge exceeds the capacity of the environment to cleanse itself, measurable ecological and social damage occur. The measurement of this damage is carried out in the traditional fashion by estimating the economic losses to the harmed parties. The aggregate social costs of the effluent can be measured in terms of dollar damage, P, and level of effluent above the capacity, $R_t - R_e = r_t$. In Figure 2-b the SC diverge from the OR_e after YE output is reached because the environment is no longer capable of cleansing itself;

(6) $SC_t = W * R_t + P(r_t)$

therefore, ecological and economic damage occur.

From this information the marginal social costs MSC caused by this output can be estimated as partial derivative of SC with respect to output. In this expression, the MSC of any particular output depends on the rate of change of the discharge below the environmental capacity of $\partial R/\partial Y$, the rate of change of

(7) $$\frac{\partial SC}{\partial Y} = \frac{W\partial R}{\partial Y} + \frac{R\partial W}{\partial Y} + \frac{R\partial r}{\partial Y} + \frac{r\partial P}{\partial Y}$$

producers or consumers surplus $\partial W/\partial Y$, the rate of change of discharge above the environmental capacity $\partial r/\partial Y$, and the rate of change of the value of damage caused by the environmental pollution $\partial P/\partial Y$. Although the value of each of these partial derivatives and parameters is an empirical question, intuitively their values seem likely to be: $\partial R/\partial Y \geq 0$, $\partial W/\partial Y \geq 0$, $\partial r/\partial Y \geq 0$, $\partial P/\partial Y \geq 0$, $W \geq 0$, $R \geq 0$, $P \geq 0$, and $r \geq 0$.

In the simplified world shown in Figure 2-c, $\partial R/\partial Y = \partial r/\partial Y = b$ and $\partial W/\partial Y = \partial P/\partial Y = 0$. The MSC is a step function. If $Y < YE$, then $MSC = W * b$ and if $Y_t > YE$ then $MSC_t = (W + P)b$. In this situation each additional unit of production initially reduces the environmental cleansing capacity and the value of the environment by $W * b$ if $Y_t < YE$. If output should rise to $Y_t > YE$, the MSC of this output increases abruptly to $(W + P)b$ as the output causes environmental damage.

The implication of the revised measurement of social costs can be seen by reanalyzing the five cases on a regional and global basis as originally examined in an earlier section. If the MB_o exists under our revised theory, a regional

[8]This idea was suggested by Professor Jim Murray in discussion at the Mid-Continent Regional Science Meetings in Manhattan, Kansas, 1977.

society's optimum level of output falls from Y_{to} to Y_{t-1}. In this case, the productive activity should cover all the costs of production and pay for the producer surplus generated by the assimilative capacity of the environment. Society would no longer wish to produce at Y_{to} since MB < MSC at this output. Reducing output from Y_{to} to Y_{t-1} reduces the discharge level from R_{to} to R_{t-1} in Figure 2-b. The environment continues to have more than sufficient capacity to absorb other pollutants. If MB_{t1} exists society's optimum output level falls from Y_E to Y_{to}. In this situation, society still does not fully utilize the environmental assimilative capacity available to eliminate the pollutants. At Y_{to} the producers or consumers find that the MSC of their environmental discharges just equal the MB of their consumption or productive activity. Society would increase its production to YE when either MB_{t2} or MB_{t3} prevails since $MB_{t2} = MB_{t3} = MSC_t$ at this production level. Society would find that any additional output beyond YE will cause the MSC to increase markedly as the increased production fully utilizes the environmental cleansing capacity and causes damages to the ecology and society.

A regional society will increase production of goods and services beyond YE only if MB rises above MB_{t3} to, say MB_{t4}. In this situation, society finds that the additional benefits of production and consumption are so great that they exceed the environmental damage and social costs. Society is willing to sacrifice the environment and impose damage on some of its institutions for the additional benefits of the increased productive activity. However, society has significantly reduced its optimum output under the new measure of SC when compared to the old. If SC includes the cleansing value of the environment, society finds that MB_{t4} = MSC when output rises only to Y_{t1} rather than Y_{t2} using Classical Theory of SC.

While a regional economy may indefinitely produce at Y > YE, the global economy is restricted to producing at Y < YE if the earth's ecology is to remain hospitable. If the global economy attempts to produce at Y > YE so that R > RE for too lengthy a period of time, the environment of the earth may be irreparably damaged. The SC of such damage may be so high that they are unacceptable no matter what the MB are of the production. In this situation society must efficiently and equitably allocate the environmental assimilative capacity to various productive activities by setting W to reflect both global and regional priorities. In some regions W may be set very low to encourage the full use of the assimilative capacity of the environment. Implicitly, this has already been done for many regions surrounding our great cities. In these areas W = 0 and society has used the assimilative capacity of the environment completely. In fact, society has usually produced at a level where Y > YE and R > RE causing considerable damage to the ecology of our urban areas. However, if society is going to abuse the ecology in one region, it can do so only by underusing the assimilative capacity of the environment in another to ensure that the global assimilative capacity is not exceeded. For every region where Y_1 > YE and R_1 > RE, the society must ensure that another region exists where $Y_2 < YE_2$ and $R_2 < RE_2$ and $R_1 \leq R_2$ so that the global Y $\leq$ YE and R $\leq$ RE.

Society may achieve a global environmental balance by evaluating the assimilative capacity differently for each region during a given time. Society may wish to set W very low for a city like Chicago ensuring that the assimilative capacity of the environment will be fully utilized. Thus, Chicago will produce at Y > YE and discharge R > RE for this region. Naturally, some of Chicago's pollution will spill into Wisconsin, Indiana, or downstate Illinois. Arrangements must be made to evalute Chicago's pollution impact on these other regions. Chicago would then have to transfer funds interregionally to ensure that both equity and efficiency are maintained on a global basis. On the other hand, society may wish to set W very high for areas like the Minnesota Boundary Water Canoe Area, BWCA. In this situation, SC and MSC will be very high. Even if MB is also high, society will still underutilize the assimilative capacity of the environment in this region. Thus, if Chicago's pollution intrudes the BWCA, then Chicago should be forced to pay the cost of polluting this area on an interregional transfer basis.

The evaluation of the environmental assimilative capacity allows society to set global and regional priorities for utilizing its environmental resources. Some regions become productive areas overutilizing the environment's assimilative capacity to provide material wealth for society. At the same time, other regions may underutilize the environmental assimilative capacity to ensure continuation of the existing regional and global ecology.

Conclusions

This paper suggests that the current theory of SC significantly underestimates the externalities of pollution. Current theory of SC does not evaluate the assimilative capacity of the environment. Using this defective theory society will have a tendency to overproduce or consume and overuse the assimilative ability of the environment on a global scale. If the theory of SC is revised to accurately measure the producer or consumer surplus generated by the assimilative ability of the environment, then society will adjust its economic activity and lower its use of the environment until MB equals the higher revised MSC. Society can set priorities by correctly evaluating both the regional and global assimilative capacity. At a regional level, society can set priorities by actively deciding to overuse the assimilative capacity in one area to achieve economic objectives while offsetting this discharge by underutilizing the assimilative capacity in another area. In this manner society may balance off the overused regional ecology with an underused regional ecology to obtain a global ecological equilibrium. This regional and global priority system depends upon the accurate evaluation of both regional and global ecological assimilative capacities.

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