ECONOMY AND ECOLOGY IN SUSTAINABLE DEVELOPMENT

Since The Club of Rome presented the results of its studies in the early 1970s, economists, environmentalists, developmentalists, and social scientists have acquired a new frontier to "butt their heads against": i.e. the biophysical and ethico-social limits to world economic growth. On the process, the concept of *sustainable development* has gradually replaced *economic growth* to become the central concept in formulating economic strategies for future economic progress.

This book is an attempt to reunite two concepts which have historically grown diametrically opposed, i.e. economy and ecology, bringing to light the breadth and depth of the aspects of sustainable development.

This effort has a global significance in the face of green consciousness:

> ...to our great surprise and embarrassment we know that nature never dies a solitary death, more often than not it dies in a chain of deaths. Ecological losses affect people across nations, regions, and even generations. It is with this frame of mind that a new vision must be found to encompass ecology as part of the macro-economics needed to save our planet.

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GROWTH AND ENVIRONMENTAL DEGRADATION: IN PURSUIT OF ALTERNATIVE APPROACHES AND MEASUREMENTS

IWAN J. AZIS

The term "sustainable development" is fast-becoming a generic category for almost every innovation on environmental idea. Meanwhile, frustration mounts over the struggle to turn the term into a usable concept and integrate it into the practice of development planning. While the number of thoughtful studies on the concept of development has been steadily increasing, progress is slow and only a handful of those studies are producing operational concepts. Ignorance on the part of policy makers, deliberately or undeliberately, further complicates the problem.

The slow progress in the construction of operational model has been, among other constraints, due to difficulties in the measuring the (almost) unmeasurable. Many attempts have been made to generate appropriate measures, however crude, to reflect a more balanced picture of sustainable economic progress. The search for better indicators is in order. Those measures are believed necessary for the policy formulation that is consistent with a sustainable development scenario. In such a scenario, the environmental damage (costs) and improvement (benefits), which are often coined as externalities in conventional economics, ought to be internalized. If this is not done, the concept of sustainable development would be even more difficult to adopt.

Similar to other development issues, there seems to be little dispute about the assertion that what cannot be measured does not exist, or at least cannot be considered known. Perhaps it is partly for this reason that economics, as a science, has almost become a branch of mathematics with measurements lying at its base. GNP (Gross National Product), or GDP (Gross Domestic Product), is only one which perhaps is the most often used indicator. But there is much debate that the GDP does not sufficiently reflect the level of welfare of society. Despite wariness of the accuracy of GDP as a measure of social welfare, national policies continue to focus on increasing the GDP, whether total or per capita. Economists have never directly claimed that GDP is a measure of human welfare. But it has become convenient, if not appropriate, to use which encourages policymakers and economists to quote the GDP in this context.

Active search for alternative measures has been undertaken. Some allowances target an adjusted GDP to take into account damages and improvements of the environment, some go even further by calculating non-monetary components of voluntary and domestic sectors. Another category of efforts is based on the presumption that improving the GDP is a hopeless step for it will never be able to capture the essence of welfare and society's utility. Among others Nordhaus and Tobin (1973) have pioneered the attempt. Perhaps the most popular alternative indicator is the Physical Quality of Life Index (PQLI), which combines statistics of infant mortality, literacy and life expectancy into a weighted composite. However, a completely different approach is determined to abandon the idea of single indicator in favor of a framework of indicators showing various components of welfare individually (see for example Anderson 1990). Obviously all the above approaches are not mutually exclusive.

This paper will highlight the connection between environment and economic growth, particularly but not solely in connection with the use and depletion of natural resources. By first outlining a justifiable background of the need

to adjust the standard GDP with changes in material and environmental resources, the discussion is expounded towards the search for alternative measurements. Some examples using the Indonesian case will be presented.

1. Ecology, Economy, and Sustainable Development

Why connect those three? The common denominator is the globe's life support systems, that is the ecosystems on which the world economy depends. When we describe our physical surroundings as a collection of possible uses, we are basically establishing linkages between economics and ecology. These possible uses, also called "environmental functions" (see for example, Hueting (1990)), will eventually compete with each other. When such a state is reached, the element of choice along with the concept of scarcity surface and the environment will have an economic aspect. The conflict is likely in the nature of inter-generational, in which the choice is between unsustainably maximizing production or growth in the short-run, of let's say tropical rain forest, or using environmental functions of the forest in a more sustainable way. In a standard dynamic model it refers basically to a conflict between maximizing growth in the short-run and reaching an ecologically sustainable scenario in the longer run (see also the appendix).

It is not too farfetched to assume that the world, or rather the globe, have almost reached an ecological crisis if they have not already. The depletion of the earth's natural resources and loss of biodiversity, the degradation of air, land, water quality, the accumulation of greenhouse gases leading to changes in climate, and the depletion of the ozone layer, are only a partial list of the increasing ecological crises the world is witnessing. The origins of the such a trend are mostly related to economic activities characterized by wasteful consumption and energy use patterns (many are in developed countries). Population pressures and poverty are also determining factors often plaguing developing nations. It is believed that unless a different mode of economic activity and policy is implemented, the sustainability of the ecosystems would be endangered and sustainable development is likely untenable.

For conventional economists, the present perception of the relationship of economy and ecology might not remain convincing. Standard economic textbooks hardly present an explicit connection between environmental damage and economic structure; even the quoted examples are seldom of an ecological-economic nature. When confronted with demonstrable examples, they are quick to response by forcibly incorporating ecological factors into the model. Unfortunately, the incorporation is via the exogenous line and often in a static-partial manner such that the simulation results of the model are unable to capture the essence of the (two-way) connection between ecology and economy. Another unfortunate implication of the approach is the constant recognition that taking care of the environment is always inefficiently costly and therefore should be put in the lowest priority.

In fact, by using practical examples it does not require intricate reasoning to explain the existence of a direct link between ecology and economics. For example, the adverse effects of agricultural activities in upland areas on many economic- related activities have been often cited by many studies. The soil fertility decreases as soil erodes. This could easily take place in the absence of crop diversification, better crop management and soil conservation programs. Upland agriculture can also intensify siltation in irrigation in dams hampering both the hydropower production capacity and the agricultural irrigation supply. Food crop activities in upland areas may also reduce the water holding capacity of the catchment area which will result in reduced water flow in dry seasons and floods in the rainy seasons. This set of factors has the potential to adversely affect the outputs of agricultural production and other sectors and can eventually retard the economic growth potential.

Another instance pertains to environmental pollution. To

promote growth of agricultural products often chemical substances are abundantly applied. This practice is likely to intensify induce environmental pollution, which is another type of ecological damage triggered by the use of organic and inorganic substances in agricultural production. The examples are countless. Biologists, chemists and other scientists will have no difficulties in providing further illustrations. Yet, even the above examples of externalities are incomplete. Loss of species, for example, is not taken into account.

The question of sustainability is undoubtedly very relevant to the relationship of ecology and economics. When the concept is applied in the two categories of natural resources, i.e. material and environmental resources, a broad policy implication will follow. In the case of material resources the policy would be to harvest the resources at a rate that does not exceed regeneration rates (for renewable resources) or to invest in the development of material substitutes (for non-renewable resources). In the case of environmental resources the production waste emissions should not exceed the renewable assimilative capacity of the local environment. Clearly, the implementation of those policies requires accurate measurements and appropriate indicators. Wrong signals and improper indicators could lead to poor policy.

2. Correcting GDP for the Depletion of Natural Resources

On the basis of the distinction between (natural) material and environmental resources, the concept of correcting GDP could also be classified accordingly. In this section we deal with measuring the depreciation of material resources, although the alternative concept discussed in the next section is applicable not solely for environmental resources.

There are three types of material resources: mineral, biotic and inflowing resources. Mineral resources are non-living and practically non-renewable. In the Indonesian case oil and gas are the most important examples. The two constitute 43% of the nation's total exports and roughly 18.2% of total GDP (1990 data).[1] Biotic resources are living species and conditionally renewable. Despite the limited stock, repeated flows of services could be secured under a proper management. Wood is perhaps the most prominent biotic resource for Indonesia. Inflowing resources are for all practical purposes renewable in the sense of today's exploitation will have a limited impact on tomorrow's availability. Solar radiation, ocean currents and the hydrological cycle are in this category.

Tables 1 & 2 show the application of an accounting framework combining "the net-price" method and "the depreciation approach" used to generate the adjustment component of oil and gas depletion for the standard GDP. The table depicts the opening stock, addition and reduction of the resources in physical unit to yield the net flows, and then by applying the net-price method the corresponding monetary units are obtained.[2]

Notice that the rent or net-price in US$/brl is based on the export f.o.b. price, implying that the per-unit economic depreciation of oil, generally known as "user cost", is determined as the difference between the market value of a resource and its costs of extraction (captured by factor payments). In other words, resources were assumed to be efficiently managed. Obviously this is rather hard to swallow. Facts indicate that this is not the case, i.e. resources are being depleted too fast, and therefore the user cost will definitely be greater than the listed net-price.

Another criticism to the approach concerns with the absence of the discount-rate of the net-price. The counter argument clings into the assumption proposed by Miller & Upton (1985) and Landefeld & Hines (1985) which assert that based on the theory of optimal depletion of exhaustible resources the future increases in the net-price would occur at a rate equal to the discount rate for alternative investments. Thus, it is identical to adopting the present value of future net-revenues under the assumption that the rate of future net-price increases will equal the discount rate.

Looking deeper into the appropriate concept of net-price, which is treated as almost the equivalent of shadow price, the first criticism is indeed valid and insolvable. The shadow price is a very attractive concept but by far is the most difficult information to yield. In fact, shadow prices for environmental functions can be constructed only in exceptional circumstances. A follow-up consequence of this limitation would require finding a more appropriate proxy variable for shadow prices.

In the case of material resources, the adoption of the assumption equating the rate of future increases of resources and discount rate could be maintained, at least temporarily until we find a better proxy and as long as an additional condition is imposed, particularly on those resources that are non-renewable. The additional condition is a policy action necessary to secure a sustainable development scenario. More specifically, a fraction of receipts from the sale of resource, we call it capital content of the receipts, which is total receipts minus income, should be invested (and not consumed) at interest rate **r** in order to have the same income stream in real terms.[3] This idea is concurrent with Hicks' standard definition of current income, i.e. part of receipts which, if devoted to consumption would leave the earner no worse off at the end of the accounting period. For a mathematical derivation of income

1. When total effects (direct and indirect) are calculated in the input-output sense, the role of these resources in the Indonesian economy would certainly be much greater.

2. Among the users of such an approach are: Repetto, World Resource Institute (1987), Azis (1989), Azis (forthcoming) and IUC-EC-UI (1989).

3. This component, which at the macro level needs to be subtracted from the standard GDP, is the equivalent of "user cost" or, as coined by Daly (1989), the "defensive expenditures".

associated with such a concept the readers may refer to the appendix which is based on Dasgupta & Maler (1991), or see also Azis (1991).

Assuming that the relative prices of the resource and the goods and services on which the stream of income will be spent remain constant, the fraction of capital content and income in total receipts do not change. Should, on the other hand, the relative price of goods and services rise, the capital proportion to be set aside must be larger.[4]

Clearly, the concept suggests that the wealth accrued from the exploitation of natural resources should partly be saved for future generations and not be squandered on consumption. Ward (1982) went on even further by recommending that the rent component of the value-added generated by the extractive industries be appropriated to a national reserve fund. In order to sustain revenue flows, this fund could then be invested with the prevailing market rate. Although the recommendation raises a separate issue from that of adjusting GDP, it does imply the recognition that the use of natural resources constitutes a diminuation in wealth. Hence, it is parallel with the concept of true income and capital content of total receipts from the extraction of natural discussed earlier.

With such a concept we would be able to understand better what happened with the oil price trend in the 70s. The fourfold increase in oil price was not only due to the alleged cartelization of supply (by OPEC) but it could also in fact be explained through the standard equalization of marginal cost and price. As long as the user cost (capital content) is included in the price of oil, the discussion on the determinant of the "oil crisis" ("oil boom" for Indonesia) leave no room for dispute.

4. See Salah El Serafy, "The Proper Calculation of Income from Depletable Natural Resources", in Ahmad Y J, El Serafy S & Lutz E (eds), *Environmental Accounting for Sustainable Development*, A UNEP-World Bank Symposium, 1989.

Would there be further (macro) policy implication of the above setting? Basically, what we would like to secure is the capitalized value of the receipts at interest rate **r** of the finite series (up to period **n**) equals the capitalized value of the infinite series of income at the same (market) interest rate. Therefore, the greater the **r** the stronger the tendency to exhaust resources. This would imply that a faster depletion of resources at the expense of further scarcity for future generations is considered profitable. It is along this line of argument that the policy of high interest rates to curb inflation is not only undesirable for encouraging investment but not conducive to sustainable use of non-renewable resources.

The net-price model and depreciation approach are also applicable to biotic resources. Table 3 displays the depletion accounting for the forest sector. Notice that there are three sources of stock addition: growth in logged forest, growth in plantation and reforestation. The reduction factors are: harvesting via production and logging damage, deforestation and degradation. While the deforestation refers to transfers of forest lands to other uses such as shifting, permanent cultivation and other infrastructures, the degradation denotes the forest deterioration due to either natural disasters (pests, earthquake and fires) or destructive exploitation of forest resources in logging operations, grazing and fuelwood collection. After taking the addition and reduction components, the closing stock which will become the new opening stock in the following year is derived by adding those components to the initial opening stock.

Similar to the previous cases of oil and gas, the monetary values in Table 3 are obtained by employing the rent which is derived from the difference between f.o.b. price and the harvesting cost. Consequently, the use of this price is also under attack since it is far from accurately reflecting the shadow price of the biotic resources. Therefore, a new approach should be sought.

Nevertheless, the depreciation approach is economical, effective, straightforward and largely based on data already collected for other management purposes. Furthermore, despite its limitation, the practical relevance of the approach is quite strong. As already discussed elsewhere,[5] (see also Figures 1 and 2), under a relatively "normal" rate of forest degradation in 1987, the total net depletion reached US$ 2.6 billion, which is greater than US$ 2.3 billion export values deriving from forest products (logs, plywood, sawnwood and other wood-related products). Even such a striking example is still underestimated. The depletion figures has so far taken no account of the loss of enormous ecological values due to the depleted forest.

Another striking finding could also be in the case of oil sector. For some years the monetary values of oil depletion exceeds the yearly export earnings. When the combined oil & forest depletion is accounted, in the first half of 1980s a considerable portion of depletion is observed.

Recall from the earlier discussion that one of the conditions required to give a stronger relevance to the approach is the implementation of a policy to invest part of the receipts (the capital content) in other productive capital. In this connection, Figure 2 demonstrates that in most years the depletion adjustment offsets a major part of gross capital formation. What is more stunning is that in 1978, 1980 and 1982 the adjusted investments (AINV) were even negative, implying that gross domestic investments fail to exceed the depletion. This suggests that in those years the nation has actually drawn down its asset base. On the other hand, in 1979, 1983 and 1987 the discovery of new petroleum reserves was linked to the positive depletion adjustments.

5. See Iwan J. Azis, The Relevance of Environmental Economics in Sustainable Development, in *Asian Economic Journal* vol V, and Iwan J. Azis, "Economic Development and Recent Adjustment in Resource Rich Countries: The Case of Indonesia", in Takao Fukuchi & Mitsuhiro Kagami (eds.), *Perspectives on the Pacific Basin Economy: A Comparison of Asia and Latin America*, Institute of Developing Economies & The Asian Club Foundation, 1989.

3. Alternative Concept to Correct the Losses of Environmental Functions

Even if the (conditional) policy action is taken, the application of depreciation approach remains affected by the absence of shadow prices. Furthermore, it is much more difficult to tackle the degradation of (natural) environmental resources by applying the approach without having a standard representing the maximum allowable use of environmental function in order to secure a sustainable development. This is partly due to the fact that unlike material resources the environmental resources provide mainly services instead of goods to the production and consumption process. Services from these resources, such as air, water and soil, are prerequisites for human life and more importantly they are not able to be substituted with other types of natural resources or man-made capital. It is in this respect that an alternative approach is needed.

In spite of frequent mention of shadow prices in economic theory, only under exceptional circumstances can shadow prices for environmental functions be constructed. A widespread application of measuring the costs for improving the environmental resources have been provided by various micro studies. These elimination costs could be treated as production costs of an environmental functions such that a supply curve for environmental functions is derivable.[6] This is not so with demands for environmental functions.

Despite the existence of some methods to estimate the preference of an individual or a society, e.g. the willingness-to-pay method, in practice the use of these types of models are almost pointless. There are too many disturbances in conducting the survey along this line. A situation

6. The elimination costs denote the costs incurred for doing away with the burden on the environment.

where some people are doubting about the participation of others (Prisoner's Dilemma) is one example. Furthermore, it is widely acknowledged that there is a considerable difference between stating one's willingness to spend money on something and actually pay for it. Even if in a few cases the method is suitable, transforming it into a macro context (e.g. correcting the GDP) is absolutely cumbersome. Therefore, deriving a demand curve for environmental functions from the standard microeconomic approach would appear almost impossible and certainly very expensive. Yet, the urgency of the matter demands some quick actions, even if at the cost of lacking a theoretical completeness.[7] However, actions with no support of any theoretical basis are not only unconvincing but also risky.

In the past decade, efforts to generate the society's awareness towards the importance of environmental factor in the whole process of development seem to have given encouraging results. Presenting scenarios similar to the one displayed in Figures 1 and 2 should be able to draw the attention of society and policy makers to correct the conventional measure of economic progress. Along with many other salutary studies, it certainly contributes to the fact that now society worldwide has increasingly declared themselves in favor of sustainable economic development. The point is how to exploit this awareness in an effective way such that an operational concept could be devised.

To a large extent, the increasing awareness can be conceived as the society's preference upon which some standards are derivable. Based on such a preference and standards, we could yield an inelastic "demand curve", which is a perpendicular line at the point of predetermined standards on the abscissa (see Figure 3). Since the abscissa measures the availability of environmental functions in physical unit, the distance between the present condition (point A) to the standard point (point S) represents activities needed to replace the environmental damages generated by environment-burdening activities. The cost of replacement, which is measured by the distance between A_c and S_c, should then become the equivalent of capital content (the definition of which has been discussed earlier in the preceding section). This portion should not enter the income flows and therefore ought to be deducted from the standard GDP.

It is not too difficult to imagine that complete and accurate data needed to reflect the present state of environment (to locate point A) will appear crucial for the whole exercise. Inaccurate identification of the present state of environment will easily mislead the estimates of replacement costs and hence not match the policy efforts. However, despite the complex nature of the information, most of the needed data are actually not new.[8] These data are available scattered among various sources; they simply ought to be compiled in a more systematic way before any calculation is made. Collaborative work with data collecting agencies, most particularly the CBS, seems inevitable. Table 4 displays an actual example (from the Norwegian case) of sectoral economic activities and the corresponding air emis-

7. The alternative approach discussed here was primarily inspired by a remark made by Minister Emil Salim when the author and his Dutch colleague, Roefie Hueting, discussed with him about the practicability of an environmental accounting for policy action. Mr. Salim's remark was (quoted from the Hueting's note): "In my policy-making I need an indicator in money terms for losses in environment and resources, as a counterweight to the indicator for production, viz. national income. If a theoretically sound indicator is not possible, then think up one that is rather less theoretically sound".

8. They are however likely considered new to many economists. It is precisely due to this fact why studies on environment and modeling sustainable development require knowledge from multi-disciplinary fields. The problem is, there is no single field called multidisciplinary. Collaborative works among different scientists are therefore the only solution.

sions. Similar tables can also be constructed for water, soil and other environmental resources.[9]

Information for locating point S should reflect the cut-off point beyond which development activities are not sustainable. The standard may range from air quality (e.g. SO_2 and Pb level), sustainable soil level (for example, the degree of some chemical wastes contained in a volume of soil or the fraction of topsoil in a specified agricultural landsite), to an acceptable standard of water quality (e.g. the BOD level). When this approach is applied to material resources, the S point should denote the maximum sustainable use of the resource. The use and extraction beyond such a level will be considered unsustainable.

True, that as in many other cases non-technical (political) pressures will need to play roles when a standard such as point A is to be imposed within a society. A consensus in political process is consequently needed. However, it should be kept in mind that sustainable standards we are talking about can actually be set up with the available knowledge and technology. Hence, they must be, as far as is possible, scientifically determined. Even the process of reaching a consensus could be achieved with scientific methodology.[10] It is also worthwhile to note that environmental standards have dimensions of time nor space. The distinction from place to place would be only in the time required to improve environmental conditions (the distance between A and S). Given the constant level in the present state of the environment, one country may need less time

9. Some examples with the explanation of questionnaires used to deduce information reflecting the state of environment could be read in Netherlands CBS, Department for Environmental Statistics, *Environmental Statistics at the Central Bureau of Statistics The Netherlands*, (undated).

10. One of the powerful methods to generate compromised perceptions from conflicting opinions is known as the "Analytic Hierarchy Process" (AHP). The method could also be used to measure quantitatively the environmental impacts of a development project. See for example, Azis (1990).

to reach the state of sustainable development than others if the environmental laws and the enforcement in the respective country are stricter.

4. Concluding Remarks

The discussion above may generate some motivation for us to establish environmental factors that can be integrated into development planning and policy, both at micro and macro level. Yet, much work remains to be put toward the design of development and measurements and modelling that fit that concept including pursuit of more operational models to enhance, not substitute, the existing ones.

This eternal search is the norm of scientific thinking. Meanwhile, destruction of the environment continues at a growing rate, presenting the luminous threat of obliteration, if different modes and policies are not put into effect. It should be questioned whether the design of concepts and measurements is truly necessary unless they are intended for application to make some corrective actions.

Unsustainable patterns of consumption in many developed nations should take much of the blame for the past deterioration of the globe's environmental condition. Without their action and considerable changes in attitudes the construction of sustainable development concept will be rather meaningless.Consider the following illustration quoted from Daly (1990). The US currently uses about 1/3 of annual world resource flows. If R denotes the world resource consumption, then R/3 is the current US resource consumption, and R/3 divided by 250 million is the present per-capita US resource consumption. Given the current 5.3 billion world population, the world per-capita resource consumption is R divided by 5.3 billion. For future world per-capita resource consumption to equal the present level of US per-capita consumption, R will need to increase by some multiple factor. Assuming constant population, this multiple factor (let's denote it by M) times R divided by 5.3 billion must then equal R/3 divided by 250 million. Solving for M gives 7, implying that world resource flows must increase seven-fold if all people are to consume resources at the present US average. Even if this seven-fold increase is considered, there is a gross underestimate of the increase in environmental impact that such an increase would present.

The point is, developing nations cannot and should not act alone. If the world's society demands for less destruction of the forest, for example, some kinds of revenue substitute ought to be provided by developed countries who import most of the forest products. This will either create additional development funds for forest-abundant nations without destroying the forest in an unsustainable way, or in the longer-run may force consumption patterns in the industrial countries to change. A consensus among developing nations is not any less important. If only one developing nation acts, viz. reducing the rate of forest exploitation, and the industrial countries are able to redirect their source of imports to other developing nations, the world's environment is not changing for the better and, still worse, at the same time the conventional notion of economic Pareto-optimum is absent.

One final word of reflection on this subject. Concepts, models and measurements are necessary but by far insufficient for establishing a world's sustainable development. The touchstone for social evolution will always be human understanding, inventiveness and acts, not the success of macroeconomics or computer models. After all, human beings are not automatons that their future can be mechanically traced by computer or models. The role of the concept and more comprehensive models should be viewed as only delineations of the outer bounds of possibility for transpiring development process that will sustain.

Table 1
Indonesia: Oil Resource Accounts, 1985–1987

	Physical Units (million of barrels)			Monetary Accounts (US$ million)			Unit Values			
	1985	1986	1987	1985	1986	1987		1985	1986	1987
(1) Opening Stock	8981	8694	8478	223526	201797	80966	(A) Export value (mUS$)	7175.5	3975.1	4393.5
(2) Addition:							(B) Export Volume (mbls)	257.6	289.6	255.8
Discoveries & Net							(C) FOB Price (US$/brl)	27.9	13.7	17.2
Revision	144	243	445	3342	2321	5541	Factor Payments (US$/brl)	4.6	4.2	4.7
(3) Reduction: Production	431	459	423	10004	4384	5267	Rent (US$/brl)	23.2	9.6	12.5
(4) Net Resource Flow	-287	-216	22	-6662	-2063	274				
(5) Revolution: Opening Stock				-15067	-118768	24596				
Closing Stock	8694	8478	8500	201797	80966	105836				

Source: - The Physical Units (1) and (5) World Oile stimated proven world reserves of natural gas; P. Cockroft and M. Joenoes, "Potential for Increased Oil Production in Indonesia", Table 2 Column 5.
- (2) Oil Statistics of Indonesia 1983 and 1987, Table III.1.2
- (4) NRF counted from (1) n+1 - (1)n
- (A) and (B) from Oil Statistic of Indonesia, Table V.1.1

Table 3
Indonesia: Forest Resource Accounts, 1985–1987

	Physical Units (million of barrels)			Monetary Accounts (US$ million)			Unit Values			
	1985	1986	1987	1985	1986	1987		1985	1986	1987
Opening Stock	19764	19670	19560	802768	733222	653610	FOB Export Price	95.72	95.72	95.72
Addition:	21	22	22	551	506	439	Harvesting Costs	54.34	58.64	64.30
A. Growth in Logged	16	16	16	418	375	318	Primary Rent	41.38	37.08	31.43
B. Growth in Plantation	0	0	0	0	0	0	Secondary Rent	26.07	23.36	19.80
C. Reforestation	5	6	6	133	131	121				
Reduction:	115	132	131	3397	3667	3053				
A. Harvesting	27	42	39	1112	1571	1236				
a.1. Production	17	26	25	695	982	772				
a.2. Logging Damage	10	16	15	417	589	463				
B. Deforestation	75	77	79	1957	1801	1567				
C. Degradation	13	13	13	328	294	249				
Net Change (rounded)	-94	-110	-109	-2845	-3161	-2614				
Revaluation: Opening Stock				-66701	-76450	-99872				
Closing Stock	19670	19560	19451	733222	653610	551125				

Table 2
Indonesia: Natural Gas Resource Accounts, 1985–1987

	Physical Units (million of barrels)			Monetary Accounts (US$ million)			Unit Values			
	1985	1986	1987	1985	1986	1987		1985	1986	1987
(1) Opening Stock	6000	65000	80000	178876	211300	164386	(A) Export value (mUS$)	3801.0	2847.5	2543.6
							(B) Export Volume (mbls)	139.9	140.6	155.4
(2) Addition:							(C) FOB Price (US$/brl)	27.2	20.3	16.4
Discoveries & Net Revision	6879	16905	9053	22362	34737	12115	Transportation Costs	3.99	3.99	3.99
(3) Reduction: Production	1879	1905	2053	6108	3914	2747	Liquifying CpstsRent	2.85	2.85	2.85
- Condensate	299	276	321	972	567	430	Factor Payments (US$/brl)	1.8	1.7	1.9
- Natural Gas	1580	1629	1732	5136	3347	2318	Rent (US$/brl)	18.5	11.7	7.6
(4) Net Resource Flow	5000	15000	7000	16254	30822	9368	Rent (US$/1000 scf)	3.3	2.1	1.3
(5) Revolution: Opening Stock				16171	-77737	-57325				
Closing Stock	65000	80000	87000	211300	164386	116429				

Notes: 1 BOE = 5.7 x 1000 SCF
1 SCF = 0.1754 x 0.001 BOE
Transportation & Liquifying Costs are assumed 70 cent/scf and 50 cents/scf respectively

Source:
- The Physical Units (1) and (5) World Oil - estimated proven world reserves of natural gas
- (2) Oil Statistics of Indonesia 1983 and 1987, Table III.1.2 and Table III.2.3
- (4) NRF counted from (1)n+1 - (1)n
- (A) and (B) from Oil Statistics of Indonesia, Table V.1.1

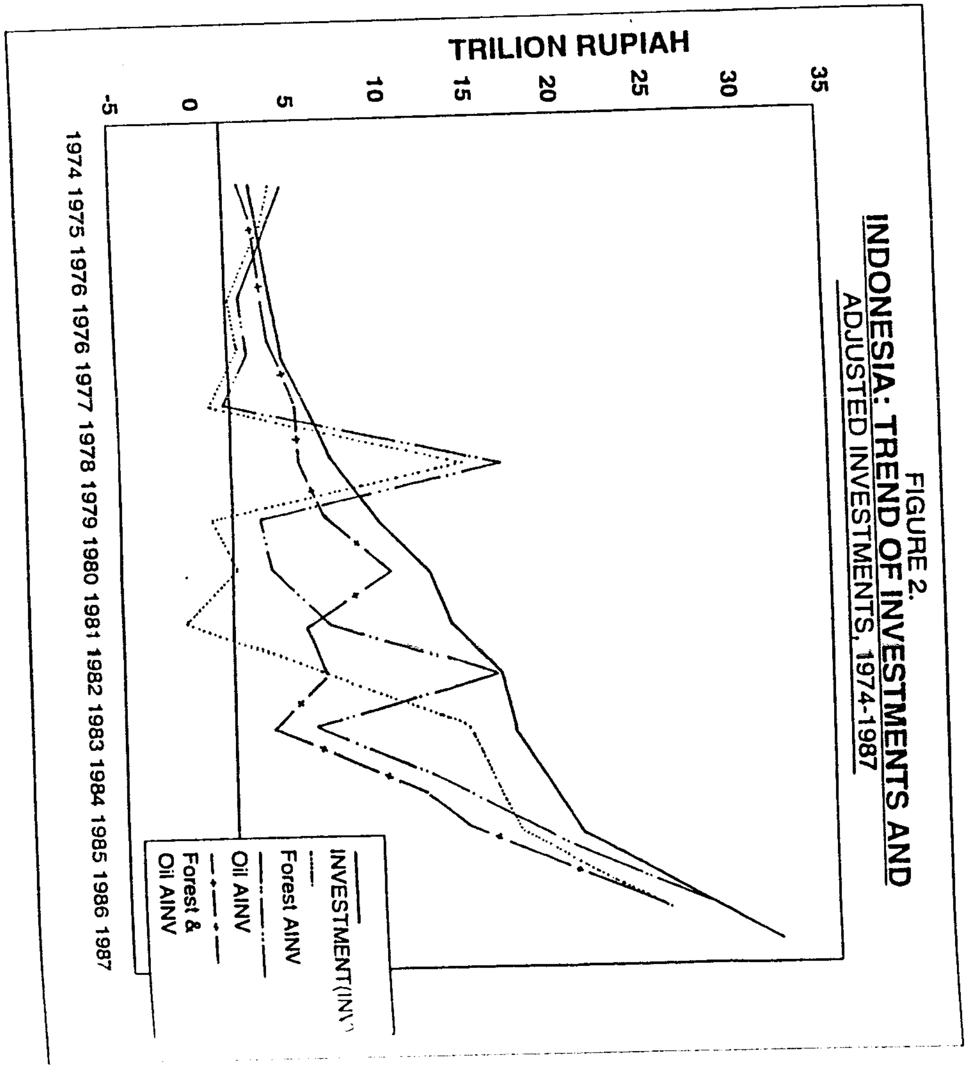
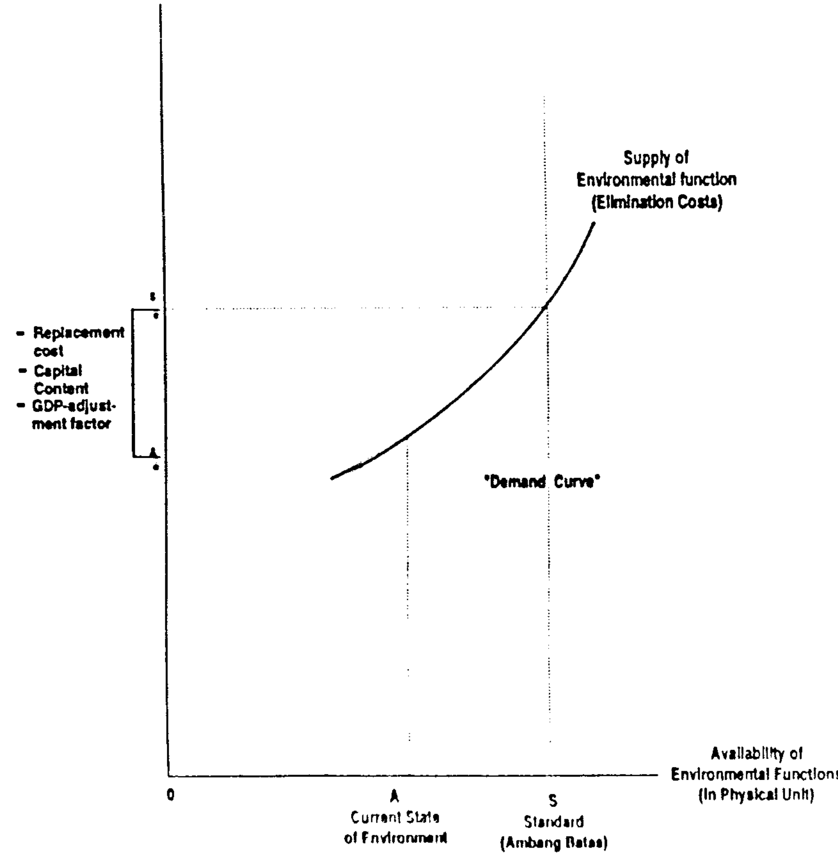


FIGURE 2.
INDONESIA: TREND OF INVESTMENTS AND
ADJUSTED INVESTMENTS, 1974-1987

Figure 3

Alternative Concept to Derive Supply and Demand Curves of Environmental Functions



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Appendix

Consider the following dynamic optimization problem:

$$\text{Max}\int_0^\infty e^{-rt}U(q_c,\ F(r_i,\ q_i,\ L_o),r_c,L_r)\,dt$$

subject to

1. $q_i + q_c + I_i + I_c = f(l_i, k_i, s_i, r_{cu}, r_i, r_c)$
2. $r_{iu} = q(s_i, L_c, K_c)$
3. $r_i = r_{i^*} - r_{iu}$
4. $L_i + L_c + L_o + L_r = L$
5. $dK_j/dt = I_j - 0_jK_j\ ;\ j = i, c$
6. $dr_c/dt = g.r_c - r_{cu}$

U(.) indicates the household utility function, and F(.) is the household production function within which the enviromental resource r_i, the productive goods q_i and the own-labor services L_o are the relevant inputs. Notice that beside the goods consumed (q_c) and free-time of labor work (L_r), the stock of enviromental resource r_c is also included in the utility function. There are two environmental resources in the model: r_i used for the household production and r_c consumed directly to affect the household utility function.

The model is distinct from the conventional model in the following sense. Environmental resources r_i can take various forms, the most common of which is land with its corresponding natural resources. Many conventional models have rarely paid due attention to land as an important production factor (apart from the period of the Physiocrats). Although the role of land related to the agricultural sector is recognized in classical economics, in their analysis only capital and labor were regarded as the main welfare generators. Similarly, in the neoclassical thinking land is treated merely as the supplier of constituents subsequently worked up by labor and capital. It is therefore not suprising that these models fail to explain the link between economy and ecology, the most crucial element of a sustainable development concept.

It is known that finding the solution of the above optimization model requires the aplication of optimal controls. The first con-

straint of the problem indicates the one-good (aggregate) production function, where I_i and I_c are, respectively, the gross investments in sector i and c (i is the productive enviromental sector and c is the consumption goods sector; refer to q_i and q_c above). K indicates the reproducible capital, s denotes the residuals generated and subscript cu indicates the use of resources.

Under the environmentally concerned development, firms specializing in the improvement of environment (call it productive environment sector, e.g. pollution control firms) are likely to exist. Such firms' production function is shown by the second constraint, where subscript iu indicates the size of the resource use. Thus, as shown in the third constraint, r_i is the remaining amount of resource input needed for the household production process. In the case of non-polluted water, for example, its use for the industrial production amounts to r_{iu}. Given the availability of non-polluted water in each period (r_{i^*}) the remaining amount would be r_i.

The fourth constraint pertains to the size of labor time (e.g. man-month), which is assumed exogenous. Constraints number 5 and 6 denote the growth function of capital in sector i dan c and the growth function of the resource stock respectively.

The Hamiltonian of the problem is:

$$\begin{aligned} H = U &- \alpha\,[q_i + q_c + I_i + I_c - f(L_i, K_i, S_i, R_{cu}, r_i, r_c)] \\ &- \beta\,(r_i + r_{iu} - \dot{r}_i) + \tau\,[r_{iu} - Q(s_i, L_c, K_c)] \\ &- \sigma\,(L_i + L_c + L_o + L_r - L) + w(I_i - d_iK_i) \\ &+ \Omega\,(I_c - \delta c K_c) + r(g.r_c - r_{cu}), \end{aligned}$$

and the stock prices are determined from the following set of differential equations:

$$\frac{dw}{dt} = -\frac{\delta H}{\delta k_i} + r.w$$

$$\frac{d\Omega}{dt} = -\frac{\delta H}{\delta k_i} + r.\Omega$$

$$\frac{dr}{dt} = -\frac{\delta H}{\delta r_c} + r.r_c.$$