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Tropical Deforestation and Agricultural Development in Latin America

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TROPICAL DEFORESTATION AND AGRICULTURAL DEVELOPMENT IN LATIN AMERICA

by

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ABSTRACT

This paper contains a regression analysis of the causes of agricultural colonization in twenty-three Latin American countries. Yield growth, associated with increased supplies of non-land inputs for crop and livestock production, is found to alleviate the pressure for frontier expansion associated with enhanced demand for agricultural commodities.

TROPICAL DEFORESTATION AND AGRICULTURAL DEVELOPMENT IN LATIN AMERICA

Tropical deforestation arouses widespread concern. Available evidence suggests that global climate is being affected (Detwiler and Hall). In addition, biological diversity is threatened because tropical forests, which cover less than 10 percent of the Earth's land surface, harbor half the world's plant and animal species (Myers; Wilson).

In many countries, deforestation is the result of excessive timber extraction. As Repetto and Gillis (1988) emphasize, the royalties loggers pay for access to publicly owned primary forests in southeast Asia fall far short of stumpage values. Responding to opportunities to capture sizable rents, they are inclined to "cut and run." Although destructive logging also takes place in Latin America, deforestation in the region is primarily an agricultural phenomenon. Brazil and a few other countries have implemented projects to relocate farmers to tree-covered hinterlands. More frequently, conversion of forests into crop land and pasture is "spontaneous," being driven by various economic forces.

For the most part, the existing literature addressing those forces consists of case studies. Moran's (1983) analysis of migration to Altamira, a settlement on Brazil's Transamazon Highway, is representative. The geographic focus of this paper, by contrast, is very broad. Regression analysis is used to explain farmers' and ranchers' encroachment on tropical forests and other natural environments throughout Latin America. In particular, the possibility that frontier expansion in the region is symptomatic of agricultural *under-development* is explored.

The model and data base used to study agriculture's geographic expansion are described at the beginning of the paper. Next, the results of regression analysis are presented. Land clearing is shown to be inversely related to trends in crop and livestock yields. This finding prompts a brief discussion of the factors influencing agricultural productivity and leads to suggestions about how to conserve natural environments in the developing world.

A Model of Agricultural Frontier Expansion

Simple Malthusian explanations of tropical deforestation, which are widely circulated, leave one with the sense that "surplus people" are heading for the developing world's agricultural frontiers in droves. This is indeed happening in some places, including parts of Latin America. For the most part, however, cities bear the burden of mounting demographic pressure in the Western Hemisphere. Even under the most miserable circumstances, urban dwellers rarely move to the Amazon Basin or the Caribbean lowlands of Central America. In addition, emigrants from the countryside, where fertility far outstrips mortality, usually go to cities and towns, not the agricultural frontier. As indicated in Table 1, urbanization is a more pronounced phenomenon in the region than population growth per se.

If there is a relationship between population growth and frontier expansion, then, it is primarily an indirect one. Domestic demand for agricultural commodities is rising in most countries primarily because the number of consumers is growing. In turn, increased demand for food enhances derived demand for land inputs to crop and livestock production.

Another potential source of demand growth is external. Pursuing development strategies that emphasized import substitution and industrialization, Latin American governments long discouraged exports by

Table I. Population Growth and Urbanization, Selected Latin American Countries

Country	Total Population in 1988	Annual Growth, 1980-88	Urban Population in 1988	Annual Growth, 1980-88
Brazil	144 million	2.2 percent	108 million	3.6 percent
Colombia	32	2.1	22	3.0
Costa Rica	3	2.3	1	1.9
Ecuador	10	2.7	6	4.7
Guatemala	9	2.9	3	2.9
Honduras	5	3.6	2	5.6
Mexico	84	2.2	60	3.1
Paraguay	4	3.2	2	4.5
Peru	21	2.2	14	3.1

Source: IBRD

levying taxes and over-valuing domestic currencies (Valdés). In recent years, however, these distortions have been reduced in a number of countries. As a result, specialization has increased in the production and export of agricultural commodities in which the region holds a comparative advantage.

All else remaining the same, increased domestic or international demand for agricultural commodities leads to an outward shift in the sector's extensive margin. But the magnitude of that shift depends on two "supply side" factors. The first is a "land constraint." The second is the supply of "non-land" inputs in the agricultural sector (e.g., human capital and managerial talent).

The land constraint on settlers' behavior largely reflects property arrangements. Where all land, agricultural and non-agricultural, is privately owned, frontier expansion is influenced by some of the opportunity costs of land clearing. In particular, agents of deforestation are forced to take into account the income associated with timber production.

Along Latin America's agricultural frontiers, however, all opportunity costs of creating new crop land and pasture are, from a settler's perspective, external costs. Because destruction of natural vegetation is a prerequisite for formal or informal property rights (Mahar; Southgate et al.), nobody is in a good position to internalize forestry rents. In addition, a settler who is slow about clearing land runs the risk that somebody else will "jump" his claim. Accordingly, colonists deforest immediately whenever agricultural rents can be captured by doing so (Southgate).

Given the nature of frontier tenurial regimes in Latin America, the land constraint on colonists' behavior is important only if virtually all soils that are both accessible and suitable for crop or livestock production have been occupied by farmers and ranchers. In a non-statistical analysis of deforestation in Brazil, Schneider et al. (1990) point out that soils featuring both those characteristics are getting scarcer when the gap between frontier and infra-marginal land prices declines. Unfortunately, sub-national data on land values are not good enough in most Latin American countries to allow price differentials to be used as a barometer of land scarcity.

In this study, current agricultural land use was compared with land use capabilities in order to determine whether or not agricultural colonization is seriously constrained. As indicated in Table 2, natural conditions do not favor continued frontier expansion in two Andean countries: Bolivia and Peru. In addition, the frontier is all but closed in Uruguay and five Central American

Table 2. Current versus Potential Agricultural Land Use in Selected Latin American Countries with Widespread Nutritional Deficits

Country	1987 Agricultural Land[1]	Potential Agricultural Land[2]
Bolivia	30,149,000 HA	30,031,000 HA
Colombia	17,480,000	43,973,000
Ecuador	7,646,000	12,532,000
El Salvador	1,343,000	1,320,000
Haiti	1,399,000	645,000
Honduras	4,315,000	3,267,000
Peru	30,845,000	33,565,000

Sources: 1. FAO, 1989A

2. OAS.

countries: Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala. In Haiti, agriculture's extensive margin has advanced well beyond what natural conditions warrant. The prospects for frontier expansion are also limited in the Dominican Republic and Jamaica.

Agricultural colonization is also affected by the availability of non-land assets for crop and livestock production. As those assets are formed, yields increase and substitution away from land takes place. Consequently, the pressure to create new crop land and pasture is eased.

Principal factors affecting agriculture's geographic expansion having been identified, let us turn to specification of the dependent variable as well as the regression model itself. Since property arrangements oblige agricultural colonists to ignore the value of tree-covered land, it makes little sense to use the ratio of cleared area to remaining forests as a dependent variable. Instead, growth in the area used to produce crops and livestock (AGLNDGRO) appears on the left-hand side of this paper's regression model of the causes of frontier expansion in Latin America:

$$AGLNDGRO = B_0 + B_1\ POPGRO + B_2\ EXPGRO + B_3\ YLDGRO + B_4\ NOLAND \ . \qquad (1)$$

The coefficients of population growth (POPGRO) and agricultural export growth (EXPGRO), which both tend to stimulate frontier expansion, are expected to be positive. By contrast, the coefficient of yield growth (YLDGRO), which is associated with the formation of non-land assets in the agricultural sector, is probably negative. Finally, NOLAND is a dummy variable indicating that closure of the agricultural frontier has occurred or is imminent. Its coefficient is expected to be negative.

Data

The twenty-four countries listed in Table 3 comprise the sample used in this study. Data on agricultural land use, population growth, exports, and agricultural yields for each country were obtained from annual publications of the Food and Agriculture Organization of the United Nations (FAO) as well as the International Bank for Reconstruction and Development (IBRD).

For twenty-one of the countries, data on crop land and pasture (FAO, 1989A) were applied to the following logarithmic formula in order to calculate the regression model's dependent variable:

$$AGLNDGRO = 100\ [LOG\ (1987\ ag\ land) - LOG\ (1982\ ag\ land)]\ /\ 5 \ . \qquad (2)$$

This approach was not appropriate, however, for determining dependent variable values for Bolivia, Mexico, and Paraguay because land use data for those three countries are very questionable.

Table 3. Data Used in the Regression Analysis

Country	Frontier Expansion[1] (AGLNDGRO)	Population Growth[2] (POPGRO)	Export Growth[3] (EXPGRO)	Yield Growth[4] (YLDGRO)
Argentina	-0.1% p.a.	1.4% p.a.	-8.5% p.a.	-0.5% p.a.
Belize	1.2	2.4	2.2	---
Bolivia	0.4	2.7	0.0	-1.4
Brazil	0.6	2.2	-3.5	3.2
Chile	0.1	1.7	17.5	3.6
Colombia	0.7	2.1	0.0	1.0
Costa Rica	1.1	2.3	5.2	1.5
Cuba	0.7	1.1	-4.3	-0.9
Dominican Republic	0.1	2.4	-7.4	0.1
Ecuador	2.0	2.7	11.4	-0.2
El Salvador	0.1	1.3	-8.5	-3.6
Guatemala	0.8	2.9	-2.5	-2.0
Guyana	0.1	-4.4	0.0	-3.9
Haiti	0.0	1.8	-8.0	1.0
Honduras	0.4	3.6	3.4	0.8
Jamaica	-0.3	1.5	0.0	3.5
Mexico	0.6	2.2	14.0	1.7
Nicaragua	0.8	3.4	-14.1	-4.8
Panama	0.7	2.2	-6.0	1.7
Paraguay	1.0	3.2	0.0	3.1
Peru	0.1	2.2	0.0	1.8
Surinam	3.2	1.1	0.0	-9.3
Uruguay	-0.1	0.6	-8.2	0.5
Venezuela	0.3	2.8	0.0	4.1

Sources: 1. FAO, 1989A and WRI

2. IBRD

3. FAO, 1989B

4. FAO, 1989A

Remote sensing studies conducted by the FAO suggest that annual deforestation currently amounts to 117,000 HA in Bolivia and 615,000 HA in Mexico (WRI). By contrast, FAO (1989A) reported that crop land expanded by just 24,000 HA and that pasture declined by 250,000 HA between 1982 and 1987 in the former country. According to the same source, Mexico had exactly 74,499,000 HA of pasture in 1972, 1977, 1982, and 1987.

In Paraguay, estimated deforestation is 212,000 HA per annum (WRI). However, the area planted to crops was supposed to have risen by 210,000 HA between 1982 and 1987 and pastures were supposed to have increased by 3,460,000 HA in the same period (FAO, 1989A). Instead of reflecting an actual shift in the agricultural frontier, the latter change is probably indicative of range lands being reclassified as pasture.

Because of these incongruities between deforestation and agricultural land use data, AGLNDGRO values were calculated for Bolivia, Mexico, and Paraguay by dividing estimated deforestation (WRI) by 1987 agricultural land (FAO, 1989A). This substitute procedure probably understates actual frontier expansion since forests are not the only natural environment being penetrated by farmers and ranchers.

With respect to the regression model's first independent variable, POPGRO, the IBRD's (1990) estimates of annual population growth during the period, 1980 through 1988, were used.

Estimates of annual growth in agricultural exports were obtained by applying trade data (FAO, 1989B) for each of the twenty-four countries in the sample to the following regression:

[LOG (exports in year t) - LOG (1983 exports)] = G (year t) , (3)

where the range of "t" was 1984 through 1988. For two-thirds of the countries listed in Table 3, the regression coefficient, G, serves as a measure of EXPGRO. For the remaining eight countries, however, EXPGRO was held to zero because the null hypothesis regarding G was accepted with a confidence interval of 90 percent.

Calculation of the third independent variable in the regression equation involved two steps. First, FAO's (1989A) index of crop production in 1982 was divided by crop land in the same year (FAO, 1989A) to obtain yields for 1982. Yields for 1987 were obtained in the same fashion. Second, a procedure like the one described in equation (2) was applied to identify annual yield growth during the intervening five years:

$$YLDGRO = 100\,[LOG\,(1987\ yields) - LOG\,(1982\ yields)]\,/\,5\,. \qquad (4)$$

Based on a comparison of current agricultural land use and land use capabilities (see preceding section), the value of the land constraint dummy variable, NOLAND, was set equal to one for the following eleven countries: Bolivia, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Peru, and Uruguay.

Other than dummy variable values, the full data set used in regression analysis is presented in Table 3. As can be seen, AGLNDGRO varies considerably from country to country. Between 1982 and 1987, agriculture's extensive margin actually receded in Argentina, Jamaica, and Uruguay. In several other countries, frontier expansion was negligible.

Compared to EXPGRO and YLDGRO, POPGRO does not exhibit much variation. Only one country, Guyana, lost population, due to heavy emigration. Between 1980 and 1988, population growth exceeded 2.5 percent a year in seven countries. Annual rates of increase were between 1.5 percent and 2.5 percent in nearly half the sample.

Values of EXPGRO and YLDGRO are widely scattered. Agricultural exports declined in countries that suffered civil conflict, maintained policies that discouraged crop and livestock production, or both. In light of increased domestic consumption of agricultural commodities (and, in many countries, increased exports), yield trends have been disappointing. Only in Brazil, Chile, Jamaica, and Venezuela did annual percentage yield increases exceed rates of population growth. The ratio of crop and livestock output to agricultural land actually declined in nine countries.

Other than a weak correlation between EXPGRO and YLDGRO, multicollinearity is not a major problem in the data set. It is particularly interesting to note that there is no strong linkage between YLDGRO and the dummy variable indicating the presence of a serious land constraint (NOLAND). The governments of countries where that constraint holds have apparently been slow to encourage formation of substitute assets in the agricultural sector.

Regression Results

Indices of crop production being unavailable for Belize, that country had to be deleted from the sample used in the regression analysis. With data for the remaining twenty-three countries (Table 3), ordinary least squares estimation yielded the following results:

$$\begin{aligned} AGLNDGRO = \; & \underset{\substack{(0.161) \\ (2.876)}}{0.463} + \underset{\substack{(0.066) \\ (3.773)}}{0.249}\, POPGRO + \underset{\substack{(0.014) \\ (2.214)}}{0.031}\, EXPGRO \\ & - \underset{\substack{(0.033) \\ (-6.000)}}{0.198}\, YLDGRO - \underset{\substack{(0.205) \\ (-3.127)}}{0.641}\, NOLAND \end{aligned} \qquad (5)$$

ADJ $R^2 = 0.669$ DW = 2.065 SSR = 3.489 F = 12.098

For a cross-sectional study, an adjusted R^2 of 67 percent is very good, particularly since aggregate national-level data for a heterogeneous group of countries have been used. Dummy variables for war, inclement weather, inflation risks, and the like could have been introduced. But to maintain a sharp focus on linkages between frontier expansion and agricultural development, this was not done. That the F-statistic exceeds 8.290 -- which is the minimum value for rejecting the hypothesis that there is no linear relationship between AGLNDGRO and the four independent variables (99 confidence interval) -- reenforces the conclusion that this paper's simple model is a satisfactory framework for analyzing encroachment on tropical forests and other natural environments in Latin America.

The signs of all parameter estimates are consistent with what one expects. The two rows of figures under the regression coefficients are standard errors and t-statistics, respectively. Using a two-tail test and a 99 percent confidence interval, one rejects the null hypothesis for the coefficients of POPGRO, YLDGRO, and NOLAND. At a 95 percent confidence interval, the null hypothesis is rejected for EXPGRO's coefficient as well.

Interpretation of the coefficients is straightforward. In a country where natural conditions do not favor frontier expansion (i.e., where the value of the dummy variable, NOLAND, is 1 instead of 0), the annual increase in crop land and pasture is expected to be 0.641 percentage points lower than would be the case if soils that lend themselves to crop or livestock production were "unoccupied." Of more direct relevance to the focus of this paper is that a Z percent increase in yields offsets nearly four-fifths of the frontier expansion otherwise induced by Z percent population growth. Alternatively, the same Z percent yield increase can compensate for 6xZ percent growth in agricultural exports.

How to Contain Agricultural Colonization

If shifts in agriculture's extensive margin were driven exclusively by increasing or decreasing demands for agricultural commodities, the prospects for containing frontier expansion in Latin America would be very bleak indeed. Throughout the region, populations are overwhelmingly young. With numbers of women capable of bearing children expected to rise for many more years, continued population growth is inevitable, even with the decline in fertility rates currently taking place in nearly every part of the Western Hemisphere (IBRD). As the number of people demanding to be fed increases, pressure on natural resource inputs to agricultural production will mount.

Unfortunately, this scenario is being played out in many parts of the Western Hemisphere. Consider, for example, the case of Ecuador, which is the most crowded country in South America.

As reported in Table 3, Ecuador's population has been growing by nearly 3 percent a year and, between 1983 and 1988, annual increases in agricultural exports amounted to 11.4 percent. The latter rate was exceeded only in Chile and Mexico. Unfortunately, demand growth has not been matched by productivity increases in Ecuadorian agriculture. Indeed, yields actually declined between 1982 and 1987. Under these circumstances, dedicating more land to crop and livestock production has proven to be essential. At 2.0 percent per annum, Ecuador had the second highest rate of frontier expansion in Latin America between 1982 and 1987. Surinam's rate (3.2 percent a year) was higher only because its initial base of crop land and pasture was tiny.

Unlike El Salvador, Nicaragua, and a few other nations, Ecuador cannot pin the blame for stagnating productivity on civil conflict. Disappointing yield trends were instead a consequence of limited investment in non-land assets. In particular, the scientific base underpinning crop and livestock production is weak in the country.

As Whitaker (1990) points out, research and extension networks are highly fractured in Ecuador. Separate entities created for agriculture, forestry, and other sectors of the rural economy do not cooperate on basic scientific research. Similarly, coordination among narrowly focused divisions of the extension service is limited. In addition, funding is meager. Real spending on agricultural research, for example, declined 7.3 percent a year from 1975 through 1988. Having fallen to 0.17 percent of agricultural GDP, research expenditures compare poorly with spending by neighboring countries (Whitaker).

Given the state of Ecuadorian agriculture's scientific base, yields are low in the country. This means that growing demands for crops and livestock have to be met by bringing more land, which is usually of marginal quality, into production. Two-thirds of the increased crop production occurring in Ecuador between the middle 1960s and the middle 1980s, for example, were accounted for by frontier expansion. Improved productivity explained only the remaining third (Whitaker and Alzamora).

Contrasting with what has taken place in Ecuador is the recent performance of Chile's agricultural economy. If yields had not risen in the latter country during the 1980s, 17.5 percent annual growth in agricultural exports combined with 1.7 percent annual population growth would have induced frontier expansion exceeding 1.0 percent a year. But because yield increases were also impressive, agriculture's extensive margin remained stable.

Chilean agriculture has become more productive because application of a full range of non-land inputs has grown more intense. Farming has become more mechanized and investments in irrigation have been made. In addition, use of chemical inputs has increased. Between 1985 and 1988, for example, nitrogen, phosphate, and potash imports rose 154 percent, 120 percent, and 355 percent, respectively, in real terms. Since agricultural research and extension are strong in Chile, yield increases have also been achieved through wider use of improved varieties and cultivars (Arensberg <u>et al</u>.).

In light of the possible impacts of mechanization, irrigation, and chemical use on soil and water quality, the last source of productivity growth deserves special attention. Indeed, it is possible that investment in the scientific base underpinning crop and livestock production can allow Latin America to satisfy growing demands for agricultural commodities without frontier expansion or deterioration of renewable natural resources within agriculture's extensive margin.

This possibility is illustrated by recent initiatives of the Brazilian Corporation for Agricultural Research (EMBRAPA). At EMBRAPA's National Soil Biology Research Center, scientists have isolated nitrogen-fixing bacteria for a number of crops grown in hot and acidic soils. Most Brazilian soybean farmers now plant seeds inoculated with those bacteria. As a result, high soybean yields are maintained and annual expenditures on fertilizer have been reduced by about $1 billion (Mangurian).

Another initiative has to do with biological pest control. Scientists at EMBRAPA's National Soybean Research Center have isolated a virus that kills the velvet bean caterpillar. Applying that virus to a soybean field costs 75 percent less than spraying pesticides. In addition, toxic chemicals are not released into the environment (Mangurian).

Implications for Conservation Strategies

Some economists attempting to explain the loss of natural habitats in the developing world fall into a habit of analysis that is nearly as old as the discipline itself. Like those who advocate acreage controls to reduce agricultural commodity surpluses in the United States, they underestimate the degree to which land and other inputs to the production of crops and livestock are interchangeable. If the option of substitution is ignored, then the predictions of a simple Ricardian model of the agricultural economy hold. That is, frontier expansion is the only possible response to market or demographic "shocks."

To be sure, formation of non-land assets should reflect an agricultural economy's factor endowments (Hayami and Ruttan). For example, investment in yield-enhancing technology is not particularly urgent where land and other natural resources are abundant. Unfortunately, investment of that type continues to be marginal in many Latin American countries where the prospects for frontier expansion are limited. Put another way, agricultural under-development and encroachment by farmers and ranchers on fragile environments go hand in hand in the region.

In part, enhancing agricultural productivity requires governmental involvement. For example, many of the products of research, technology transfer, and education are "public goods." Accordingly, public spending on those activities is essential. However, policies that discourage farmers and ranchers from adopting productivity-enhancing measures also need to be reformed. Obviously, yields are bound to be low in any country where food price controls and currency distortions discourage production for domestic and international markets.

Increased productivity is not a panacea for all environmental problems arising in the agricultural sector. As indicated by the Chilean experience (see preceding section), one way to reduce farmers' encroachment on natural habitats is to increase fertilizer and pesticide applications on existing crop land. However, this can amount to solving one environmental problem by exacerbating another. Fortunately, there is an alternative. Investing in research, extension, and education allows for crop and livestock yields to increase without adverse impacts on renewable natural resources.

Finally, development of the technology needed for an environmentally sound response to mounting demands for agricultural commodities will not be enough to save Latin America's natural habitats. A re-ordering of property rights is also necessary. Vast stretches of the region's tropical forests remain, in effect, open access resources in which individuals can secure property rights by removing natural vegetation (Mahar; Southgate et al.). As long as this tenurial regime remains in place, continued deforestation is inevitable.

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BOOKS

Edward B. Barbier
Economics, Natural-Resource Scarcity and Development: Conventional and Alternative Views, Earthscan, London, 1989 (paperback £15.00)

The history of environmental and resource economics is reviewed; then using insights from environmentalism, ecology and thermodynamics, Barbier begins the construction of a new economic approach to the use of natural resources and particularly to the problem of environmental degradation. With examples from the global greenhouse effect, Amazonian deforestation and upland degradation on Java, Barbier develops a major theoretical advance and shows how it can be applied. This book breaks new ground in the search for an economics of sustainable development.

David W. Pearce, Anil Markandya and Edward B. Barbier
Blueprint for a Green Economy, Earthscan, London, 1989 (paperback £6.95)

This book was initially prepared as a report to the Department of Environment, as part of the response by the government of the United Kingdom to the Brundtland Report, *Our Common Future*. The government stated that: '...the UK fully intends to continue building on this approach (environmental improvement) and further to develop policies consistent with the concept of sustainable development.' The book attempts to assist that process.

Edward B. Barbier, Joanne C. Burgess, Timothy M. Swanson and David W. Pearce
Elephants, Economics and Ivory, Earthscan, London, 1990 (paperback £8.95)

The dramatic decline in elephant numbers in most of Africa has been largely attributed to the illegal harvesting of ivory. The recent decision to ban all trade in ivory is intended to save the elephant. This book examines the ivory trade, its regulation and its implications for elephant management from an economic perspective. The authors' preferred option is for a very limited trade in ivory, designed to maintain the incentive for sustainable management in the southern African countries and to encourage other countries to follow suit.

Gordon R. Conway and Edward B. Barbier
After the Green Revolution: Sustainable Agriculture for Development, Earthscan Pub. Ltd., London, 1990 (paperback £8.95)

The Green Revolution has successfully improved agricultural productivity in many parts of the developing world. But these successes may be limited to specific favourable agro-ecological and economic conditions. This book discusses how more sustainable and equitable forms of agricultural development need to be promoted. The key is developing appropriate techniques and participatory approaches at the local level, advocating complementary policy reforms at the national level and working within the constraints imposed by the international economic system.

David W. Pearce, Edward B. Barbier and Anil Markandya
Sustainable Development: Economics and Environment in the Third World, London and Earthscan Pub. Ltd., London, 1990 (paperback £9.95)

The authors elaborate on the concept of sustainable development and illustrate how environmental economics can be applied to the developing world. Beginning with an overview of the concept of sustainable development, the authors indicate its implications for discounting and economic appraisal. Case studies on natural resource economics and management issues are drawn from Indonesia, Sudan, Botswana, Nepal and the Amazon.

David W. Pearce and R. Kerry Turner
** *Economics of Natural Resources and the Environment*, Harvester-Wheatsheaf, London, 1990.

This textbook covers the elements of environmental economics in theory and in application. It is aimed at undergraduates and includes chapters on sustainable development, environmental ethics, pollution taxes and permits, environmental policy in the West and East, recycling, and optimal resource use.

David W. Pearce, Edward B. Barbier, Anil Markandya, Scott Barrett, R. Kerry Turner and Timothy M. Swanson
Blueprint 2: Greening the World Economy, Earthscan Pub. Ltd., London, 1991 (paperback £7.95)

Following the success of *Blueprint for a Green Economy*, LEEC has turned its attention to global environmental threats. The book reviews the role of economics in analyzing global resources such as climate, ozone and biodiversity, and considers economic policy options to address such problems as global climate change, ozone depletion and tropical deforestation.

FORTHCOMING PUBLICATIONS

Jean-Philippe Barde and David W. Pearce (eds.)
Valuing the Environment: Six Case Studies, Earthscan Pub. Ltd., London, available June 1991 (paperback £9.95)

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