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An Ecological Footprint Approach to External Debt Relief

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Summary. — This paper applies Martinez-Alier's [Environ. Values 2 (1993) 97] "ecological debt" concept to the problem of debt relief, exploring the possibility of compensatory transfers from rich to poor countries based on existing ecological balances. I employ recent estimates on ecological footprints and ecosystem values to estimate the ecological debt to be distributed among eligible transfer recipients—all less-developed countries (LDCs). The results provide a policy criterion for transfers in the event that future circumstances make large-scale international debt relief compulsory. The study probably underestimates the appropriate transfer amounts because of conservative assumptions regarding the environmental values and the size of the north's ecological debt in physical terms.

Key words — debt relief, ecological debt, ecological distribution, ecological footprint, international inequality, North–South transfers

1. INTRODUCTION

Severely-indebted less-developed countries (LDCs) often engage in economic activity that is harmful to their natural environments—such as deforestation or ecologically-degrading monocrop agriculture—in hopes of gaining adequate export revenue with which to finance their external debts (Andersson, Folke, & Nystrom, 1995; Kox, 1997; Muradian & Martinez-Alier, 2001). There has thus far been scant evidence that such activities foster economic self-sufficiency or development in general. LDCs, on the contrary, have for the most part been losing ground in relative terms (Haynes & Husan, 2000; Homer-Dixon, 1995; Pritchett, 1997; Slaughter, 1998). Furthermore, unfavorable trade relations that overwhelmingly emphasize primary products have in most cases only increased debt burdens.

The ecologically-degrading economic activities pursued by severely-indebted LDCs are in no small measure a consequence of their being able to sell their goods in international markets at "ecologically-incorrect" prices—that is, exceedingly low prices that fail to consider the environmental loss or damage consequent to the activity that generated the product. Martinez-Alier (1993, p. 106) refers to this as "ecologically unequal exchange" and argues that it gives rise to an "ecological debt" increasingly claimed by the poor. Indeed, it is widely believed that the poor are disproportionately hurt by environmental degradation in general (e.g., Dasgupta, 1995; Khan, 1997; Torras, 2001), though reliable data to support this claim remain elusive.

In this paper I apply the ecological debt concept to the problem of debt relief, exploring the possibility of compensatory transfers from rich to poor countries based on existing ecological balances. I do not argue that such ecological debt relief is necessarily warranted—though it may be—nor do I maintain that LDCs are entirely blameless for their external debt burdens—they seldom if ever are. I merely explore possible scenarios in the event that future circumstances made large-scale debt relief compulsory. The framework that I develop provides fresh policy implications for such a contingency.

The analysis consists of two parts: The first, made possible by new ecological footprint data published in the *Living Planet Report* (Loh, 2000), involves estimating the ecological debt to be distributed among transfer recipient countries in terms of area units or "ecological

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space." [1] The second part involves translating the area units to dollar values in order to calculate the compensation or transfer due to each eligible country. My findings indicate that indebted LDCs stand to gain much from an ecological transfer scheme, in many cases offsetting their entire outstanding debt. My results, moreover, probably underestimate the relevant compensation amounts because of conservative assumptions that I adopt on matters of environmental valuation and the magnitude of material flow transfers from LDCs to industrialized countries.

2. ECOLOGICAL DISTRIBUTION, ECOLOGICAL DEBT, AND THE ECOLOGICAL FOOTPRINT

Insight into the effects of environmental damage on a country's development prospects can be gained by investigating how such damage is distributed among different groups in society. Political ecologists such as Bryant (1992), Millikan (1992), and Schmink and Wood (1987) have studied how existing social, political, and ideological institutions govern property rights, and how these in turn determine land-use patterns. As often noted in this literature, differential land-use patterns not only generate different environmental outcomes, they determine the resulting "winners" and "losers" from the alternative land uses.

Martinez-Alier (1995) coins the term "ecological distribution" to describe the degree to which certain types of environmental damage create such winners and losers, and he distinguishes among three types—social, spatial, and temporal ecological distribution. By social ecological distribution he refers to the distribution of environmental damage within a local, regional, or national population. Recent work on environmental discrimination and environmental justice (Lambert & Boerner, 1997; Ong & Blumenberg, 1993; Vasquez, 1993) attends to this problem, indeed finding that the "losers" are generally the poorer or "minority" groups. Because the topic is not central to the main theme of my paper, however, I will have nothing more to say here about social ecological distribution.

Spatial ecological distribution expresses how environmental damage is distributed across—rather than within—specific populations. In the international sphere, this would include ecologically-unequal trade relations in which poor countries degrade their environments in order to remain "economically-competitive" (i.e., produce at a low market price). As expressed by Martinez-Alier (1993), such behavior gives rise to an implicit ecological debt owed mostly to LDCs by the rich countries, the latter benefiting from cheap imports without having to endure the environmental damage "external" to their manufacture.

Finally, temporal ecological distribution refers to the (social or spatial) distribution of environmental damage across different generations. Of the three forms of ecological distribution, this one has arguably received the most attention in recent years since it essentially describes the problem of achieving sustainability (see e.g., Repetto, Magrath, Wells, Beer, & Rossini, 1989; Solórzano *et al*., 1991). Temporal ecological distribution addresses inequality across generations, such as when a country directly or indirectly consumes more raw material resources than produced by the natural environment, thus reducing its size to the detriment of future generations. Temporal ecological distribution applies to rich and poor countries alike.

I argue that the sizable ecological debts held by industrialized countries are grounds for a compensatory transfer scheme aimed at reducing if not eliminating the external debt of many LDCs. The reasoning is similar to that in a hypothetical "carbon trading rights" regime (see e.g., Agarwal & Narain, 1991; Epstein & Gupta, 1991; Jenkins, 1996; Solomon, 1999), in which LDCs trade CO_2 emissions "rights" (allocated to it according to some criterion—population, GDP, or what have you) for cash or debt cancellation. [2] The transfer scheme that I develop does *not*, however, resembles the notion of a "debt-for-nature" swap. The latter entails compensation from country X for future preservation of natural environments in country Y instead of for X's role in already irreversibly degrading Y's environment. [3]

To the extent that a country is able to consume at a level that commands more material resources than available domestically, it is imposing a direct environmental cost on other countries that supply it with such means. This is, in Martinez-Alier's lexicon, spatial ecological *mal*distribution. The phenomenon supports ecologically-based, crosscountry compensatory transfers, for two reasons.

First, many erstwhile colonies—now LDCs—have a long history of providing richer countries with much of the material means to

consume at higher levels than otherwise possible, and it therefore follows that they are due some compensation for the historical hardship. One can plausibly argue that the phenomenon to some degree persists even today, although this reasoning is not pursued here. Second, notwithstanding any historical basis for such compensation, it seems that, at least in the case of the most highly indebted countries, some measure of debt relief or forgiveness is required if we are serious about their ever achieving significant economic development. If widespread debt relief is indeed inevitable at some point, spatial ecological maldistribution offers not only a justification for it, but a basis for determining specific compensation amounts.

The implied compensation scheme raises two questions, however. First, how do we measure the difference between the aggregate amount that countries consume and the aggregate material stock available to fund such consumption? Second, assuming some uniform metric, how do we translate such totals into currency (e.g., dollar) equivalents so that spatial maldistribution can be applied to the problem of debt relief?

While I defer discussion of the second question until later, the existing literature on ecological footprints provides a useful starting point for addressing the first. In its simplest terms, a country's ecological footprint is its per capita resource consumption, measured in "area units" meant to reflect the implied land area required to support it. [4] The indicator provides insight into the extent to which a county's economy is sustainable when compared with the available productive land per capita (termed "biocapacity" in the ecological footprint literature). If the land requirement exceeds the availability, the country is not on a sustainable course, and when the opposite holds, it is.

Figure 1 illustrates how spatial or temporal ecological maldistribution must be present in order for a country's ecological footprint to exceed its available biocapacity. The biocapacity arrows leading from each of the small footprint countries to the large footprint country represent the spatial maldistribution that enables the large country to increase its available biocapacity stock (depicted by arrows pointing outward in contrast to the case with

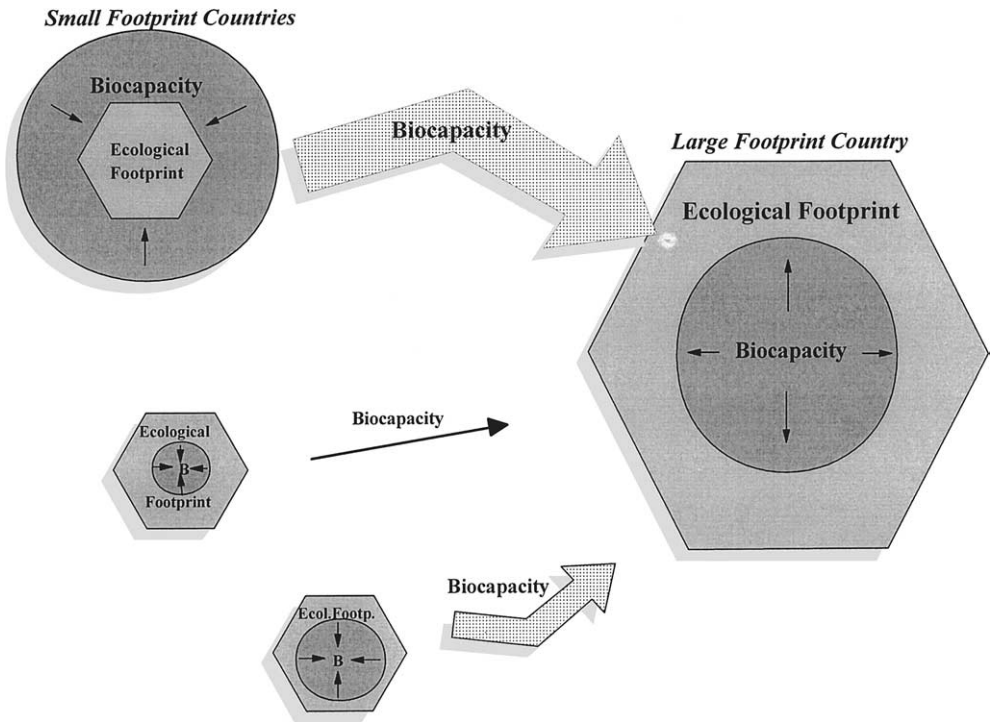

Figure 1. *An example of ecological footprints and associated biocapacity flows.*

the small countries). Yet the fact that the large country's ecological footprint exceeds its growing biocapacity implies that the country must be unsustainably harvesting its own natural resources to make up the difference—i.e., temporal maldistribution.

It is important to clarify the meaning of few terms, since I use them repeatedly in the analysis to follow. A country is in *ecological deficit* when its ecological footprint exceeds its total biocapacity, and in *ecological surplus* when the opposite holds. In contrast to the traditional accounting equivalents, however, there is no duality between "ecological" surpluses and deficits. If there were, the world as a whole would be in "ecological balance," implying that the global footprint exactly matches available biocapacity. This can only be if the present generation uses all material flows available to it, no more, no less. [5] Data from the *Living Planet Report*, an internationally collaborative effort (Loh, 2000) show that the ecological pressure of humanity on Earth at present exceeds the world ecosystem's regeneration rate.

I synonymously use biophysical capacity, biocapacity, and carrying capacity to describe the aggregate quantity of material (inputs) available, and "appropriated carrying capacity" (hereafter ACC) to indicate the biocapacity imported by some countries from others in order to help sustain a certain level of consumption in the "importing" country. *Ecological debt* is the monetary equivalent of a country's ecological deficit, and the *ecological transfer* is the monetary compensation that the externally indebted countries receive from the ecologically indebted ones.

3. METHODOLOGY

The first step in computing the required ecological transfers is calculation of the total ecological deficit on which such transfers are based. The calculation, in turn, requires identification of the ecologically-indebted countries. Among all countries in ecological deficit—that is, with ecological footprint exceeding biocapacity—I count only the industrialized countries in determining the overall ecological deficit. Aside from the "colonial legacy" argument for doing so, most externally-indebted LDCs lack the economic means with which to compensate other countries. It would therefore make little sense to include them among the transferring countries.

As for the countries eligible for an ecological transfer, mere possession of a sizable external debt would exclude few LDCs. Exempting ecological-deficit LDCs from transfer responsibility is one thing; designating them eligible for an ecological transfer would be quite another. The main point of the present analysis is that ecological deficit countries should compensate surplus ones. I therefore require possession of an ecological surplus for inclusion among the ecological transfer recipients. [6] Doing so leaves out many LDCs that are in ecological deficit—Bangladesh, China, and Egypt, for example. There unquestionably are other decision rules that one can adopt in determining the transfer recipients—such as basing the transfer on per capita ecological footprint and ignoring the biocapacity endowment—but there is no obviously superior alternative to the ecological surplus criterion. My hope is that the simple and transparent criterion described here will provoke discussion and consideration of other alternatives.

Further complicating matters is the question of what portion of the ecological deficit should be allocated to the designated surplus countries. Apportioning *all* of it among the ecological transfer recipients would imply that the entire ecological deficit is fed by carrying capacity appropriated by the ecologically-indebted countries from the recipient countries. Doing so would not be proper since temporal ecological maldistribution—i.e., unsustainable exploitation of domestic natural resource stocks—explains some percentage of the total in most if not all cases. Further assumptions are therefore necessary.

I compare and contrast outcomes under two assumed values of the ACC-to-ecological deficit ratio, 5–10%. Doing so implies that 90–95% of ecological deficits are explained by temporal as opposed to spatial maldistribution—unrealistically high, in all likelihood, but I prefer to err on the side of being too conservative. The criteria that I employ for allocating the ecological transfer amounts are total exports and population. A greater magnitude of exports implies greater economic interdependence with the outside world and, *ceteris paribus*, larger transfers of biocapacity from LDCs to support consumption in rich countries. I choose population under the alternative presumption that every individual residing in one of the ecological surplus countries should benefit equally; hence countries with large populations receive a proportionately larger transfer.

4. DATA

The ecological footprint and biophysical capacity figures that appear in the *Living Planet Report* (Loh, 2000) help us determine whether a country is in ecological surplus or deficit. As illustrated by specific country examples in Table 1, every country fits into one of four transparently-labeled categories: transferring, "doubly afflicted," "doubly blessed," and transfer recipient. For ecological footprints and biophysical capacities for *all* countries, as well as the detail behind their calculation, I refer the reader to the *Living Planet Report*. [7]

External debt, export, and population data are from the World Bank (2000). [8] While population information is available for all countries presented in the *Living Planet Report*, the same is not true for external debt and exports. Countries eligible for an ecological transfer for which the export statistic is not available only receive the compensation where population is the criterion for allocation. Countries for which external debt data are not available are ineligible for an ecological transfer, even if in principle warranted. Fortunately, there are only two such cases, Bosnia and Namibia.

I use the *Living Planet Report* and World Bank data to determine the ecological deficit and surplus countries and, as we will see, the ecological transfer amounts. All told there are 16 ecological deficit countries as of 1996 and the total deficit exceeds 3.7 billion area units, of which the United States accounts for almost half (Table 2). It means that under the 5–10% ACC assumptions the monetary equivalent of either 186.7 million or 373.4 million area units is available to be allocated among the surplus countries. Measured in area units, the ecological deficit for the entire world is just short of four billion, which means that the world is in ecological deficit to the tune of 251 million even if we disregard the 16 industrialized countries listed. In other words, in addition to any spatial maldistribution present, it is clear that the entire world at present is borrowing significantly from future generations.

Table 2. *Ecological deficit countries*

Country	Ecological deficit ('000 area units)
United States	1,791,769
Japan	638,907
Germany	313,711
United Kingdom	260,602
Italy	205,944
France	174,753
Spain	117,987
Netherlands	51,907
Belgium–Luxumberg	37,665
Greece	34,440
Switzerland	31,095
Portugal	27,211
Denmark	22,012
Austria	10,469
Ireland	9,884
Slovenia	5,526
Total for ecological deficit countries	3,733,883
Total deficit for world as a whole	3,985,481

Source: *Living Planet Report* (Loh, 2000).

In Table 3 I list the countries designated to share in the overall ecological transfer, indicating the "pre-transfer" external debt for each. In order to compensate the listed countries for their ecological surpluses, however, we must convert each country's share of the total transfer to dollar equivalents. Here matters become more complicated because no known data or estimates of area unit values exist at present. The best that we can do is to base the area unit values on published value estimates for terrain types that are most similar to the land classifications considered in the *Living Planet Report*. For this purpose I use estimates by Costanza *et al.* (1997), albeit modifying the numbers somewhat. [9]

Table 1. *Ecological footprint–external debt taxonomy, with country examples*

	External debt	Ecological debt	Country examples
Transferring countries	No	Yes	United States, Japan, Ireland, Slovenia
Doubly afflicted countries	Yes	Yes	China, India, Mexico, Iran
Doubly blessed countries	No	No	Canada, Australia, Sweden, Finland
Transfer recipient countries	Yes	No	Brazil, Malaysia, Latvia, Togo

Table 3. *External debt of countries eligible for ecological transfer, 1996 (billion dollars)*

Brazil	180.78	Ghana	6.44	Paraguay	2.16
Indonesia	128.94	Panama	6.07	Liberia[a]	2.11
Argentina	111.93	Nicaragua	5.93	Cambodia	2.10
Malaysia	39.67	Uruguay	5.90	Benin	1.59
Venezuela, RB	35.36	Congo, Rep.	5.24	Togo	1.47
Peru	29.33	Bolivia	5.20	Georgia	1.36
Colombia	28.90	Myanmar[a]	5.18	Sierra Leone	1.18
Côte d'Ivoire	19.52	Honduras	4.53	Chad	1.00
Sudan[a]	16.97	Gabon	4.31	Guinea-Bissau	0.94
Ecuador	14.50	Madagascar	4.15	Ctr. African Rep.	0.93
Congo, DR	12.83	Guatemala	3.77	Botswana	0.61
Angola	11.23	Uganda	3.67	Mongolia	0.53
Cameroon	9.54	Guinea	3.24	Latvia	0.47
Mozambique	7.57	Mali	3.01	Bhutan	0.11
Tanzania	7.36	Papua New Guinea	2.51		
Zambia	7.05	Lao PDR	2.26		

Source: World Bank (2000).
[a] Export data not available. Country only receives an ecological transfer when population is the allocation criterion.

For example, while Costanza *et al*. estimate the value of the services generated by the world's natural environment in its entirety, I only do so for a subset of the terrain types considered by the authors since not all conform to the ecological footprint methodology. Specifically, I omit desert, tundra, open ocean, ice/rock, and "urban," and include coastal marine area, forest, grass/rangeland, wetland, lake/river, and cropland. More important, I only consider "direct use" benefits listed in the Costanza *et al*. study: food production, raw materials, genetic resources, recreation, and cultural. I disregard the values of the dozen or so "indirect" or ecological benefits that are always much more difficult to estimate absent a market for such benefits. [10]

The area unit value for each land type is the net present value of its "benefit flows," which I obtain by discounting the average annual flow at a rate of 5%. Table 4 presents information on the availability of each land type as well as the NPV per hectare. The estimated value per area unit after taking the weighted average is $4,400 (in contrast to what it would be if calculated taking into account *all*—that is, market *and* ecological benefits—$36,105). This makes the total ecological debt to be allocated among recipient countries $821.5 billion in the case where ACC equals 5%, and $1.64 trillion when ACC is assumed to equal 10%.

Table 4. *Land area values*

Terrain type	Area available (million hectares)	Per-hectare net present value (1996 $s)
Coastal	3,102	$4,820
Forest	4,855	$5,300
Grass	3,898	$1,380
Wetland	330	$36,340
Lakes/rivers	200	$5,420
Cropland	1,400	$1,080
Weighted average		$4,400

Source: Costanza *et al*. (1997).

5. RESULTS

I present the post-transfer international balances for ecological surplus countries in Tables 5 and 6, contrasting the 5% and 10% hypothetical cases for ACC. Rather than provide balances for all 46 surplus countries, I show the 10 largest debtors and 10 largest "creditors"—countries that come out being *owed* money after receiving their transfer—under each scenario. The fact that all the post-transfer creditors begin as international debtors reveals the potential significance of ecological transfers to these countries.

If we assume ACC equal to 5% and allocate the ecological transfers according to total exports, only four of the 10 largest debtors previously listed in Table 3—Brazil, Argentina, Peru, and Côte d'Ivoire—remain in the top 10.

Table 5. *Adjusted debt when ecological transfer based on total exports (million dollars)*

Country	ACC = 5%		Country	ACC = 10%	
	Debt after transfer	Debt prior to transfer		Debt after transfer	Debt prior to transfer
Top 10 debtors					
Brazil	49,036	180,780	Mozambique	5,525	7,566
Argentina	43,973	111,930	Congo, DR	4,947	12,826
Peru	11,975	29,328	Nicaragua	2,078	5,932
Congo, DR	8,886	12,826	Zambia	1,760	7,054
Côte d'Ivoire	7,556	19,524	Tanzania	1,292	7,362
Mozambique	6,546	7,566	Guinea-Bissau	801	937
Cameroon	4,652	9,542	Mali	506	3,006
Zambia	4,407	7,054	Sierra Leone	399	1,179
Tanzania	4,327	7,362	Madagascar	234	4,146
Nicaragua	4,005	5,932	Laos	233	2,263
	Credit after transfer	Debt prior to transfer		Credit after transfer	Debt prior to transfer
Top 10 creditors					
Malaysia	178,389	39,673	Malaysia	396,452	39,673
Venezuela	26,160	35,360	Indonesia	151,372	128,940
Indonesia	11,216	128,940	Venezuela	87,679	35,360
Paraguay	8,693	2,162	Brazil	82,709	180,780
Latvia	5,764	475	Colombia	38,489	28,900
Botswana	5,728	614	Argentina	23,985	111,930
Colombia	4,795	28,900	Paraguay	19,547	2,162
P N Guinea	4,619	2,507	Ecuador	13,217	14,495
Gabon	3,983	4,310	Uruguay	13,129	5,901
Uruguay	3,614	5,901	Angola	12,850	11,225

If, alternatively, we assume ACC to equal 10%, *none* of the countries in the original top 10 list remain. Moreover, the post-transfer list of top 10 debtors is dominated by sub-Saharan African countries, eight of 10 all told. Despite relatively small external debts, most of the African countries in the transfer recipient group have relatively low export-debt ratios and therefore receive a fairly meager ecological transfer. Nevertheless, the largest remaining external debt—Mozambique's—is, at $5.5 billion, trivial in comparison to the pre-transfer debts of many countries.

Countries with much larger initial debts benefit proportionately more. Malaysia, Venezuela, Indonesia, and Colombia all appear among the 10 largest creditors assuming ACC equal to 5%, despite being among the 10 largest pre-transfer debtors. We add three to this group—Brazil, Argentina, and Ecuador—if we assume ACC equal to 10%. While the top 10 post-transfer debtors were mostly African countries, seven of the 10 top creditors are Latin American (and the top two are Asian).

There is also a significant change from the pre-transfer debt rankings if we allocate according to population, although not as great as in the export case. Assuming ACC equal to 5%, seven of the 10 original top 10 debtors remain in the top 10 (in fact they are the top seven post-transfer debtors). Yet only two remain on the top 10 list—Argentina and Malaysia—when we assume ACC to equal 10%. This is not surprising since neither country is very populous in comparison to other large debtors—Brazil and Indonesia in particular. More important, Argentina and Malaysia here are two of only five post-transfer debtors. Forty-one of 46 countries, in other words, become creditors after the transfer. The more equitable distribution of the $1.6 trillion dollar ecological debt in this case indicates less dispersion around the population mean than around the export mean.

Despite being the second-largest pre-transfer debtor, Indonesia is not surprisingly the largest post-transfer creditor—even assuming ACC equal to 5%—since it has the world's fourth largest population, just shy of 200 million.

Table 6. *Adjusted debt when ecological transfer based on population (million dollars)*

Country	Assuming ACC = 5%		Country	Assuming ACC = 10%	
	Debt after transfer	Debt prior to transfer		Debt after transfer	Debt prior to transfer
Top 10 debtors					
Argentina	79,594	111,930	Argentina	47,259	111,930
Brazil	32,497	180,780	Gabon	2,245	4,310
Malaysia	20,274	39,673	Panama	1,159	6,069
Venezuela	14,876	35,360	Malaysia	876	39,673
Peru	7,342	29,328	Congo, Rep.	405	5,241
Côte d'Ivoire	6,772	19,524	Uruguay	−51	5,901
Ecuador	3,755	14,495	Guinea-Bissau	−1,105	937
Panama	3,614	6,069	Bhutan	−1,201	114
Gabon	3,278	4,310	Botswana	−2,133	614
Uruguay	2,925	5,901	Nicaragua	−2,420	5,932
	Credit after transfer	Debt prior to transfer		Credit after transfer	Debt prior to transfer
Top 10 creditors					
Indonesia	52,073	128,940	Indonesia	233,087	128,940
Myanmar	34,651	5,184	Brazil	115,786	180,780
Congo, DR	28,722	12,826	Myanmar	74,487	5,184
Tanzania	20,629	7,362	Congo, DR	70,270	12,826
Uganda	14,450	3,674	Tanzania	48,621	7,362
Ghana	9,646	6,442	Colombia	43,235	28,900
Madagascar	8,449	4,146	Sudan	32,901	16,972
Cambodia	7,969	2,100	Uganda	32,574	3,674
Sudan	7,965	16,972	Ghana	25,734	6,442
Mozambique	7,335	7,566	Mozambique	22,235	7,566

Similarly, although Brazil is the second largest debtor assuming ACC equal to 5% despite receiving a sizable transfer from its 161 million population, it jumps to the second largest creditor when we assume ACC to equal 10 instead of 5%. The African countries on the whole benefit more from the population criterion—and the Latin American countries less—since six of the top 10 creditors are African as compared to one (Angola, ranked 10th) in the export case.

In addition to illustrating that there are significant potential gains for indebted LDCs, the alternative criteria for ecological transfers that I have evaluated show that the gains to different geographical areas vary significantly depending on the criterion employed. Latin American countries on the whole stand to gain more under the export criterion while African countries gain relatively more if we use population. The criterion employed appears to make little difference to Asian countries.

6. DISCUSSION AND CONCLUDING THOUGHTS

Externally-indebted LDCs stand to gain a great deal from ecologically-motivated transfers from industrialized countries. Assuming that ecological deficit countries appropriate 10% of additional carrying capacity needed from these LDCs instead of from their own biocapacity stock, many LDCs become net creditors after the ecological transfer. Among the debtors that remain when the ecological transfers are based on total exports, Mozambique's debt is largest, and it is a mere $5.5 billion. The population criterion is more equitable in that its application results in 41 of the 46 original debtor countries becoming net creditors after the transfer. The largest remaining debtor in this case—Argentina—retains a more sizable negative balance of about $47 billion. Even here the amount is less than one-half the country's pre-transfer debt.

My main objective has been to illustrate the ecological potential for significant reductions in LDC external debt burdens. The question of which countries should most gain from ecological transfers can and should be explored in greater detail, since my results are likely to be sensitive to alternative assumptions. For example, determination of the transfer recipients might be conducted on an ecological footprint per capita basis—that is, disregarding available biocapacity. Such a variation would avoid rewarding countries with relatively small populations or relatively large land masses. In addition, any alternative approach that allows for more than 46 ecological transfer recipients (as in my exercise) would have the effect of reducing average transfer. Yet the average transfer might increase substantially if we included ecological benefits in estimating the area unit value or adopted less conservative assumptions about the share of ecological deficit that is fed by carrying capacity appropriated from abroad.

I have stated that the alternative assumptions of 5% and 10% for the share of LDC ecological footprint that is appropriated by foreign countries is conservative. Still, my conclusions suggest the need to probe deeper into the relationship between ecological deficits and the actions of foreign direct investors and multinationals in LDC natural environments. While there is no question that such actions make a non-negligible contribution to the ecological footprint—and, for that matter, GDP—of both investing and host country, more extensive research on different cases, past and present, might produce the basis for informed estimates rather than hypothetical assumptions, however conservative the latter may appear.

While I have focused on the ecological debt that emerges from spatial maldistribution, the general problem of ecological footprints exceeding biocapacity has an important temporal aspect as well. Consider that the world's total ecological deficit, at 3.99 billion area units, exceeds the industrial country total that was allocated as transfers (3.73 billion). That is, the world ecological footprint exceeds its biocapacity even disregarding the 16 countries that enjoy the highest consumption levels. At $4,400 per area unit, the world deficit is valued at about $17.5 trillion. Our assumption about what percentage is "spatial" and what percentage is "temporal" does not apply here since we are talking about the total for the entire world. One hundred percent of $17.5 trillion, in other words, is what the present generation of the world's people "owes" all future generations.

Both spatial and temporal components of ecological distribution merit future research since better understanding of ecological maldistribution is critical to designing future policy solutions to global environmental problems. Each of the two dimensions implies different policy solutions. Compensatory transfers are indeed one potentially useful method of alleviating the spatial aspect of ecological deficits. Perhaps more important, they may serve the additional function of reducing or canceling outright the external debt of many LDCs, with potentially desirable economic and environmental consequences. Nevertheless, the fact that the world as a whole is in considerable deficit signifies that transfers are by themselves an insufficient means of promoting environmental sustainability. The temporal maldistribution implied by the ecological footprint analysis appears to suggest the need to reduce ecological footprints across the board. Whether it implies policy aimed at stabilizing consumption levels, developing of less material-intensive technologies, or some combination of the two, is a subject for another paper.

NOTES

1. For those not familiar with the ecological footprint literature, these and related concepts are explained in the methodology section of this paper.

2. Jenkins, in fact, also uses the "ecological debt" concept as a justification for North–South compensatory transfers.

3. Moreover, unlike the ecological transfer, the debt-nature swap generally involves a third party—typically an NGO—although this need not always be so. See, among others, Deacon and Murphy (1997), Isla (2001), and Tucker (1994).

4. An area unit is equivalent to a hectare of biologically productive space with world average productivity.

Its productivity—i.e., how much consumption it can sustain—is an average of different types of terrain with varying levels of productivity, weighted according to availability of each land type. I discuss the measure in greater detail in the data section of the paper. For more detail on ecological footprints I refer the reader to Picton and Daniels (1999), Rees (1992), Rees and Wackernagel (1994), and Wackernagel *et al.* (1999).

5. In other words, that it uses material flows as they are obtained but leaves intact the stocks that generate the flows.

6. One could undoubtedly refine the formula in such a way that the relative *magnitude* of ecological deficit or surplus would bear on the outcome. For instance, we might deem that countries with relatively small deficits or surpluses might be disregarded, that large ecological deficit LDCs be responsible for some "discounted" share of the total compensation, and that only large ecological surplus countries share in the ecological transfer. Yet the additional complexities that such considerations raise—such as how "small" and "large" are defined, for example—are beyond my present scope.

7. The detail includes the "subfootprints"—cropland, grazing land, forest, fishery, and CO_2—that make up the aggregate ecological footprint as well as the average productivity of different land types in each country.

8. I make a few adjustments to the country observations, in a couple of cases because of inconsistency between the *Living Planet Report* and World Bank data. Although data for Hong Kong are listed separately by both sources, I combine them with China. In contrast, since the footprint and biocapacity data for Belgium and Luxembourg are presented as if they were for a single country, I similarly aggregate the World Bank data for consistency. Finally, I omit Taiwan from the data set since the World Bank does not consider it separately from China.

9. I should add the caveat that many have found problems with their approach. See, for example, Ayres (1997), Norgaard, Bode, and Values Reading Group (1998), and Rees (1998). Still, Costanza *et al.* provide some plausible reasons why their calculations might underestimate the actual values (such as the indifference of the "price system" to sustainability issues, or the authors' disregard for threshold effects or discontinuities).

10. A problem often confronted in resource and environmental valuation studies, often leading to severe understatement of the relevant values. As noted by Pearce (1991, pp. 242–243), ignoring these benefits results in environmental degradation exceeding the "efficient" amount: "Typically, development benefits can be fairly readily calculated because there are attendant cash flows... Conservation [ecological] benefits, on the other hand, are a mix of associated cash flows and 'non-market' benefits. This fact imparts two biases. The first is that components with associated cash flows are made to appear more 'real' than those without such cash flows. There is 'misplaced concreteness' and decisions are likely to be biased in favor of the development option because conservation benefits are not readily calculable. The second bias follows from the first. Unless incentives are devised whereby the non-market benefits are 'internalized'...conservation benefits will automatically be downgraded... [T]hose who stand to gain from timber extraction or agricultural clearance cannot consume the non-marketed benefits. This 'asymmetry of values' imparts a considerable bias in favor of the development option."

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