The* ecor: *An international exchange unit for fair allocation of ecological capacity

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Submitted to the 2009 Amsterdam Conference
on the Human Dimensions of Global Environmental Change:
'Earth System Governance: People, Places and the Planet'

Stream 5: Allocation and Access in Earth Systems Governance

Abtract:

Studies of ecological footprint and other indicators of human use of the Earth's biocapacity indicate that humans are approaching or have already surpassed key planetary boundaries for safe operation of the human economy. A new unit of international exchange, called the ecor, could help drive the global economy toward elimination of the current ecological debt and maintain a modest biocapacity reserve. The ecor would be based on an indicator of human appropriation of the Earth's bioproductivity, such as ecological footprint, with a limited amount of ecors available for allocation among countries. Ecor accounts would be adjusted to reduce the global human ecological footprint to a level that would retain in perpetuity a minimum biocapacity reserve. Individual countries could trade ecors and perhaps borrow against the future, but would face strict penalties for exceeding their allotments. Administration of the ecor would require detailed data on the ecological impact of all traded and non-traded goods and services. A proposed global institution, the Earth Reserve, would clear ecor accounts annually, with adjustments based on trades and borrowing. It could be given the complementary authority to assess surcharges or credits for the pricing of traded goods and services, based on net ecological impact. The ecor poses a clear challenge to the current growth-insistent global economy and prevailing concepts of liberalized trade, but is justified by the need to avoid almost certain economic collapse if current growth trends continue. The ecor is a work in progress. It is introduced at the conceptual level, with the intention that further development and refinement will follow.

Introduction

The great challenge of our era is to find a way to shift from a dominant global economic ideology that seeks to increase global per capita consumption indefinitely to one that seeks fair sharing of the Earth's limited biocapacity among all of the Earth's human and non-human inhabitants. Global information on the alarming status and momentum of climate change, extinctions of species, loss of biodiversity, depletion of freshwater and other resources, ocean dead zones, population growth, topsoil degradation, deforestation, dying coral reefs, decimation of ocean fish stocks and the sheer throughput of material and energy in the human economy underscores the urgency of this challenge. (Speth 2008). This ecological reality should be the main driver of global governance of the human economy.

The ecosystems of the Earth provide all that humans consume and accumulate or assimilate all human-generated wastes. A governance framework built on an understanding of how the Earth's systems function, and of how they are currently threatened, will require rigorous and reliable mechanisms for measuring and allocating fairly the human share of the life support capacity of the Earth's biosphere and atmosphere. (Brown and Garver 2009). In view of the world's increasingly globalized economy, one key arena of opportunity for applying such an allocation mechanism is international trade. International commerce today is the engine of a global economy hell-bent on increasing perpetually its overall size, on the theory that nothing else will ensure adequate individual levels of wellbeing, measured solely by consumption. Meanwhile, the environmental Kuznets curve provides many economists the answer to environmental concerns: Free, globalized trade supposedly will allow human societies across the planet to become rich enough to innovate away environmental degradation.[1] International governance of this trade system is the domain of the World Bank, International Monetary Fund (IMF) and other international financial institutions, along with the World Trade Organization (WTO) and a smattering of regional trade institutions.

What if the goal for the global economy was not to maximize consumption through perpetual growth, but to contain the scale of the economy within the ecological limits of the Earth, enhance the integrity and resilience of ecosystems, ensure a fair allocation of the economy's benefits and burdens among its human and other inhabitants, and enhance opportunities for spiritual and intellectual development? How would international commerce operate against such a purpose? Herman Daly (1996) envisions that maximizing domestic production for internal markets, with international trade as a backstop, would be the ecologically preferable arrangement. William Rees and Mathis

[1] The environmental Kuznets curve is an inverted U-shaped curve that suggests that environmental degradation initially increases with rising per capita income but then decreases beyond a certain level of per capita wealth. (Torras and Boyce 1998). Thus, Lord Nicholas Stern states in the *Stern Review on the Economics of Climate Change* that "[r]apid growth and development will enhance countries' ability to adapt [to climate change]." (Stern 2006, xxvi). Critics of the environmental Kuznets curve point out that in many developed countries where this pattern has been observed, the environmental degradation is simply displaced to other countries with lower environmental standards. (Daly and Farley 2004, 332).

Wackernagel contemplate a trade system that would "encourage the rehabilitation of natural capital and direct the benefits of export activities to those who need them most." (Rees and Wackernagel 1996, 12). With trade operating under criteria like these, what tools could be used to limit and allocate fairly human appropriation of the Earth's limited ecosphere?

One tool that might be dusted off and re-tooled for the ecological realities of the twenty-first century is the International Clearing Union (ICU), proposed in 1943 by John Maynard Keynes during the Bretton Woods talks that led to the creation of the World Bank and the IMF. (Daly and Farley, 2004; Monbiot 2003; Brown and Garver 2009). The ICU was a proposed mechanism for stabilizing trade, designed to ensure that creditor nations would not come to dominate debtor nations. The ICU would determine trade exchange rates with national currencies through a new exchange unit for international trade, the *bancor*, and monitor any trade imbalances that arose. Should any nation develop a net trade surplus or deficit, its bancor exchange rate would be adjusted to disfavor future trade imbalances.

An updated version of the ICU would promote fair and equitable international trade that maintains the integrity and resilience of Earth systems. By adding an ecological component, bancors would become *ecors*. (Brown and Garver 2009). The ecor would be a unit of exchange established to reflect a global cap on appropriation of ecological capacity and adjusted against national accounts so as to prevent countries, either individually or collectively, from running ecological deficits.

The ecor is a work in progress. This paper is a preliminary effort at elaborating on the ecor concept. First, it presents a more detailed justification for, and explanation of, the ecor. Second, it contains a discussion of challenges, such as the administrative costs, collection and analysis of data and other obstacles in selecting and implementing ecological indicators that might be used as references for the ecor. The result is a framework for further development and refinement of the ecor.

Trade and biocapacity: why a new tool for regulating human appropriation of the Earth's biocapacity is needed

The Living Planet Report 2008 (WWF 2008) underscores the increasing proportion of global ecological impact that is attributed to international trade. The report notes a rise in the proportion of the total human ecological footprint[2] attributed to international trade from eight percent to forty percent from 1961 to 2005. (WWF 2008, 30). Increasingly, global trading patterns reflect a hyperactive import-export system, with every country seeking to be a net exporter – an obviously impossible situation, because imports and exports must balance out at the global level. (Rees 2002, 257-258). The current international trade regime relies on a myth based on comparative advantage that masks a reality in which freely moving capital favors countries based on absolute advantage, leading to concentration of wealth and market domination.[3] Id. National and corporate debt drive "a global trading system in which 'goods that could easily be produced locally flow backwards and forwards across the country . . . and across the whole world' at great ecological and social cost to most trading partners and the world at large." (Rees 2002, 257-58, citation omitted).

This is not to say that international trade is necessarily and always the ecologically most damaging way of provisioning the human economy. The ecological costs of producing something locally might be greater than the ecological costs of importing it. (WWF 2008). The solution, then, is to seek "harmonization of cost-accounting standards across countries" (Daly and Farley 2004, 329), where the costs are assessed in terms of use of ecological capacity. That is where the ecor comes in.

Another aspect of international trade is the tendency to regard trade balances solely in monetary terms, which is the general approach of economists. (Proops et al. 1999, 77). However, monetarily balanced trade can include material imbalance that in effect means that one county is exporting its ecological footprint to another. (Giljum and Hubacek 2001, 1). In contrasting trade-induced material flow and land appropriation

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[2] Ecological footprint is a measure of human use of the Earth's life support capacity, expressed in terms of hectares of productive land, that was developed in the 1990s by William Rees and Mathis Wackernagel. (Kitzes et al. 2009; Meadows et al. 2004, 3). It is discussed in more detail later in this paper.

[3] Daly and Farley (2004) clearly explain how comparative advantage, unlike absolute advantage, requires capital immobility. In theory, comparative advantage leads to the most efficient total production of goods and services, with trading partners each producing the goods and service they can produce most cheaply with their available capital, labor and resources and importing goods and services for which their trading partners have the advantage. In the real world, however, capital is highly mobile. Consequently, investments favor countries with absolute advantage, leading invariably to trade imbalances. (Daly and Farley 2004, 309-317).

with the monetary trade balance for the European Union, Giljum and Hubacek (2001) illustrate the importance of considering material or ecological flows in addition to monetary flows in considering the balance of trade from an ecological perspective. Here again, the ecor would help track and regulate resource flows so as to drive the global economy toward sustainability.

The role of the ecor in regulating human appropriation of the Earth's biocapacity

Like the Earth's biocapacity, the total amount of ecor to be allocated among the world's trading partners would be limited. The cap would be set according to the best information on the limit needed to enhance and preserve the integrity and resilience of Earth systems. National ecor accounts would be tied to a nation's management of its use of ecological capacity for domestic consumption and waste disposal, accounting for imports.[4] (Brown and Garver 2009, 120). Consumption or waste-producing activities causing a net increase in a State's appropriation of ecological function would result in corresponding charges in ecors, creating incentives against further ecological degradation. Id. Likewise, efforts by a State to increase ecological function through such activities as afforestation, reforestation and low-impact development could result in a corresponding increase of that nation's ecor credits. Id. Depending on how the ecor is formulated, these effects could be either direct or indirect.

A global institution, proposed here as the Earth Reserve, would administer the ecor in ways analogous to how monetary reserves regulate money. (Brown and Garver 2009). Compared to the ICU, the Earth Reserve would be less concerned about maintaining monetary import-export balances at the country level and more concerned with avoiding trade that produces a net increase in appropriation of ecological capacity. With the ecor, trade imbalances would not necessarily be a concern if the corresponding trade scenario resulted in the lowest use of ecological capacity for the amount of consumption and waste production involved. Indeed, given the number of developing countries like India, with populations that are already over-consuming their native biocapacities despite very low per capita consumption rates (WWF 2008), some degree

[4] It is proposed here that use of ecological capacity associated with exports would be attributed to the importing country, although it has been suggested that some attribution of the impact to the exporting country might be appropriate. (Kitzes et al. 2009).

of imbalance in trade measured in ecors is likely inevitable if the people in those countries are to have sufficient means to support themselves. (Daly and Farley 2004, 333).

The ecor concept has roots in trade mechanisms that have been considered recently, albeit with limited success and likely resistance in the WTO. For example, in early 2008, the European Commission considered assessing a carbon tariff on goods from countries with climate change restrictions less stringent than Europe's, giving those goods an unfair economic advantage. (Wynn 2008). The ecor would provide a broad and neutral framework for this type of adjustment, with greenhouse gas emissions implicitly included with all other demands on the Earth's ecological capacity that require limitation. However, the ecor would have important advantages over a tariff system. Most importantly, unlike carbon tariffs, the Earth Reserve, and not individual countries, would establish the value of the ecor, precluding accusations of protectionism. For the Earth Reserve, protectionism would mean protecting the Earth's ecological capacity so it can support the human economy for generations to come.

The ecor would have to complement other efforts at the global, national and sub-national level to protect the Earth's life support capacity. Just as no single ecological indicator can answer all ecological questions, no single policy mechanism will answer all ecological challenges that the human economy poses.

Guiding principles and a conceptual illustration of the ecor

The starting point in introducing the ecor is to describe some guiding principles and a conceptual illustration of how the ecor would work.[5] Two key elements of the

[5] The principles and guidelines for the bancor give a sense of a different set of priorities, but with some features that can be compared to the case of the ecor. The ICU and the bancor were intended to serve the fulfill the need for:

1. an instrument of international currency to make bilateral arrangements superfluous,
2. an orderly method of determining foreign exchange values,
3. a quantum of international currency that is subject to deliberate expansion and contraction,
4. a stabilizing mechanism to exert pressure on countries whose payments tend to become unbalanced,
5. starting off every country after [World War II] with a stock of reserves appropriate to its importance in world commerce,
6. a central institution to support other international institutions,

Earth Reserve's administration of the ecor are presented here. First, the ecor would operate as the unit of exchange in a global closed market[6] for the trading of a limited total allocation of ecological footprint (or other indicator) among countries – in essence, a global cap and trade system for ecological footprint. Second, as a complement to the ecor, the Earth Reserve could impose an international surcharge or credit on international transactions, adjusting market prices so as to drive the total ecological impact of the economy to levels that prevent a global ecological deficit and ensure a minimum biocapacity reserve. Proposed guiding principles for the ecor follow.

1. *The ecor would be pegged to an indicator that reflects human use of the Earth's ecological capacity.*

Attempts to measure limits on, and total human use of, the Earth's life support systems are on the rise. (Wackernagel et al. 2002). Reference to these limits would be a defining feature of the ecor. Candidates for indicators of human use of the Earth's ecological capacity include ecological footprint, human appropriation of net primary productivity (HANPP), material flow accounts (MFAs) and a composite of planetary limits. Because it is the most comprehensive and developed of these options, ecological footprint is the main indicator used for illustration here. Further discussion of ecological footprint and other candidate indicators that might be adapted as references for the ecor is presented below.

2. *Initial allocation of ecors should account for current performance against the indicator, allowing for a transition toward elimination of the ecological debt.*

Because the Earth's ecological capacity is currently over-appropriated (WWF 2008), a transition period will be necessary to bring the human economy back to levels that contain a reserve of life support capacity. This over-appropriation of life support capacity is called ecological overshoot. (WWF 2008). As formulated here, the initial allocation of ecors would surpass the Earth's ecological capacity, reflecting the current situation, and ecor accounting would then aggressively track the curve for reducing

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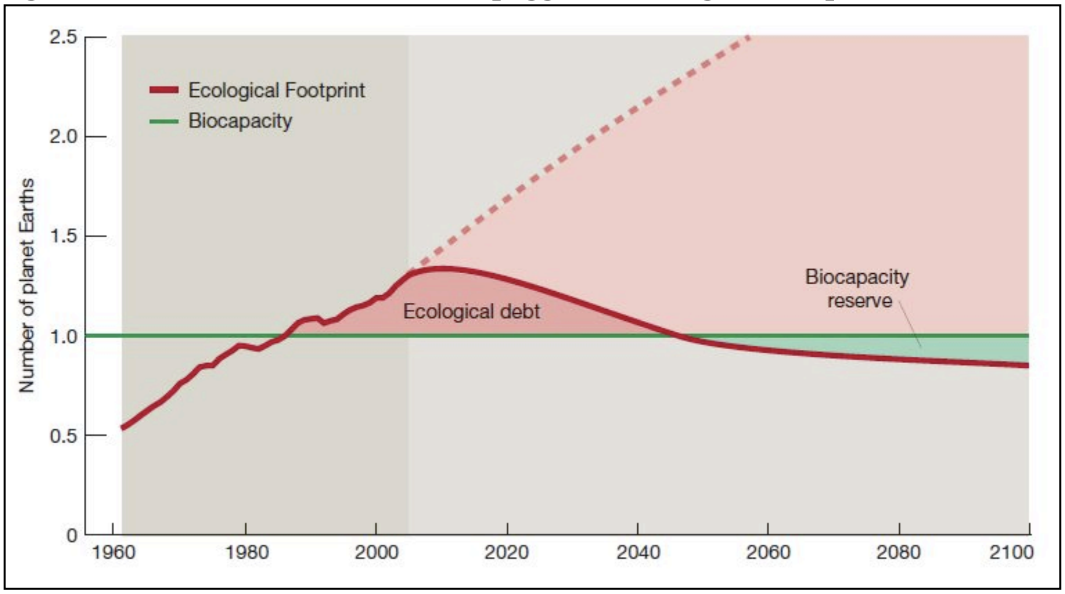
7. a means of reassurance that methods of restriction and discrimination will be unnecessary. (De Vegh 1943, 534-535).

[6] The market would be closed in the sense that speculation on ecors would be strictly forbidden.

ecological overshoot. Figure 1 shows the World Wildlife Fund's projection of a scenario to eliminate the current global ecological deficit by 2050, with a peak ecological footprint at today's levels. (WWF 2008). Although this scenario is almost certainly over optimistic, it provides a basis for illustrating the track that the ecor could follow in bringing the global economy within the Earth's ecological limits.

Figure 1. Time horizon for the ecor pegged to ecological footprint



Source: WWF, Living Planet Report 2008.

Let us assume that the initial allocation of ecors occurs in 2010, and that global and country-level ecological footprints in 2010 are comparable to 2005 footprints. Using the overshoot reduction curve in Figure 1 as a guide, the initial allocation of ecors would correlate to the total 2010 ecological footprint, and ecors would then be adjusted toward elimination of the global ecological deficit by 2050. Better yet, the global ecological footprint would be reduced further, so as to reach, and then maintain, a ten percent global biocapacity reserve by 2060.[7] The adoption of a biocapacity reserve is consistent with the notion of a biodiversity buffer, or additional set-aside of biocapacity, that is needed once the human ecological footprint is determined. (Wackernagel et al. 2002).

An initial allocation of ecors correlated to countries' current ecological footprint

[7] A ten percent biocapacity reserve is created by maintaining total ecological footprint ten percent below the overshoot limit. In other words, ecological footprint could not surpass ninety percent of the ecological footprint at which all of the available biocapacity is appropriated.

might be seen as unfair, in that countries with high per capita ecological footprints, like the United States and Canada, would receive high initial allocations. However, countries with high initial allocations would normally have a more significant challenge in reducing their footprint toward the low footprint endpoint in 2060 and beyond. For example, under an "equal sharing" scenario, this apparent initial advantage would be offset by adopting for each country a trajectory for ecological footprint toward the global average per capita ecological footprint resulting in elimination of the global ecological deficit in 2050 and establishment of a ten percent biocapacity reserve by 2060. In this scenario, the trajectory for countries with current per capita ecological footprints below the debt-free per capita average could (depending on population growth) allow for increased per capita consumption over this four-decade period. By contrast, countries with current per capita ecological footprints above the debt-free per capita average would need to decrease per capita consumption over this period.

This transition period can be illustrated with ten countries with different current ecological footprint profiles: Brazil, Canada, China, Germany, India, Mexico, Namibia, Spain, the United States and Viet Nam. Table 1 shows the population and per capita ecological footprint for those countries and the world total in 2005 (World Wildlife Fund 2008), along with projected population in 2060 (United Nations 2009).[8] Figures 2 and 3 show the ecological footprint trajectories (total footprint and per capita footprint) for those countries to reach the global per capita ecological footprint that would allow a ten percent biocapacity reserve by 2060, under the equal sharing scenario. The United Nation's medium variant projection for a world population of 9.15 billion people in 2050 is used for the world population in 2060. Assuming biocapacity is the same in 2060 as in 2010,[9] 13.6 billion global hectares (gha),[10] per capita ecological footprint that would

[8] The United Nation's medium variant projected populations for 2050 are used for the year 2060. (United Nations 2009). For simplicity, 2005 values for population and ecological footprint are used for 2010, using figures from the 2008 Living Planet Report. (WWF 2008).
[9] The actual biocapacity in 2060 will depend on a number of complex factors, such as climate change and CO_2 fertilization effects due to human-generated greenhouse emissions, some of which will likely increase biocapacity and some of which will decrease it.
[10] A global hectare is a normalized unit of land area used in ecological footprint calculations. It represents the average productivity of the different land and near-shore sea that are included in ecological footprint calculations. It is a fictional land unit, rather than an actual one. (WWF 2008).

allow a ten percent biocapacity reserve by 2060 is approximately 1.3 gha.

Table 1. Current and target country-specific populations and ecological footprints: Equal sharing scenario

Country	2005 population (millions)	2005 per capita ecological footprint (gha)	2005 total ecological footprint (million gha)	2060 projected population (millions)	2060 target total ecological footprint (million gha)
Brazil	186.4	2.4	447.4	218.5	327.8
Canada	32.2	7.1	229.3	44.4	66.6
China	1323.3	2.1	2778.9	1417.0	2125.5
Germany	82.7	4.2	347.3	70.5	105.8
India	1103.4	0.9	993.1	1613.8	2420.7
Mexico	107.0	3.4	363.8	129.0	193.5
Namibia	2.0	3.7	7.4	3.6	5.4
Spain	43.1	5.7	245.7	51.3	77.0
United States	298.2	9.4	2803.1	403.9	605.9
Viet Nam	84.2	1.3	109.5	111.7	167.6
World	6476	2.7	17485	9150	12240

Figure 2. Trajectories for total ecological footprint (million gha) toward a 10% biocapacity reserve in 2060: Equal sharing scenario

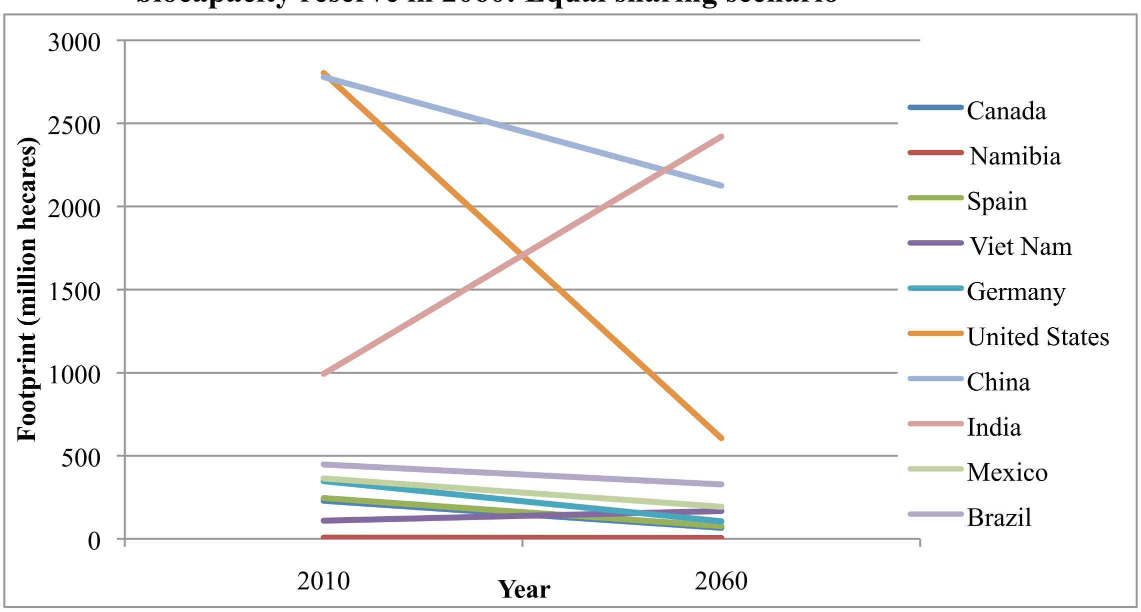
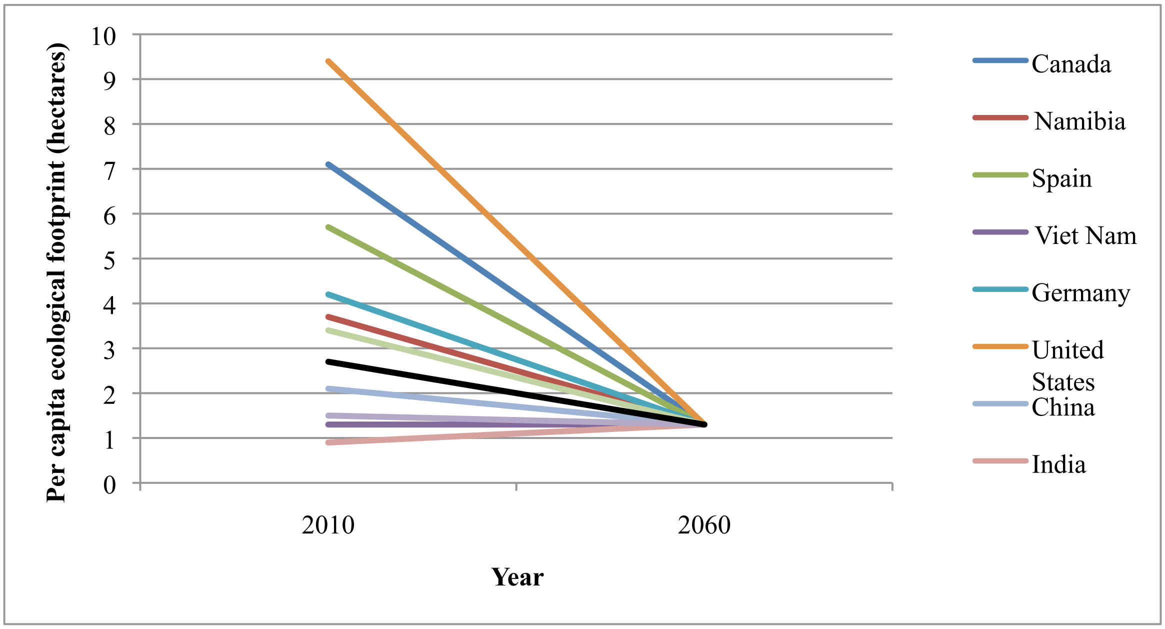
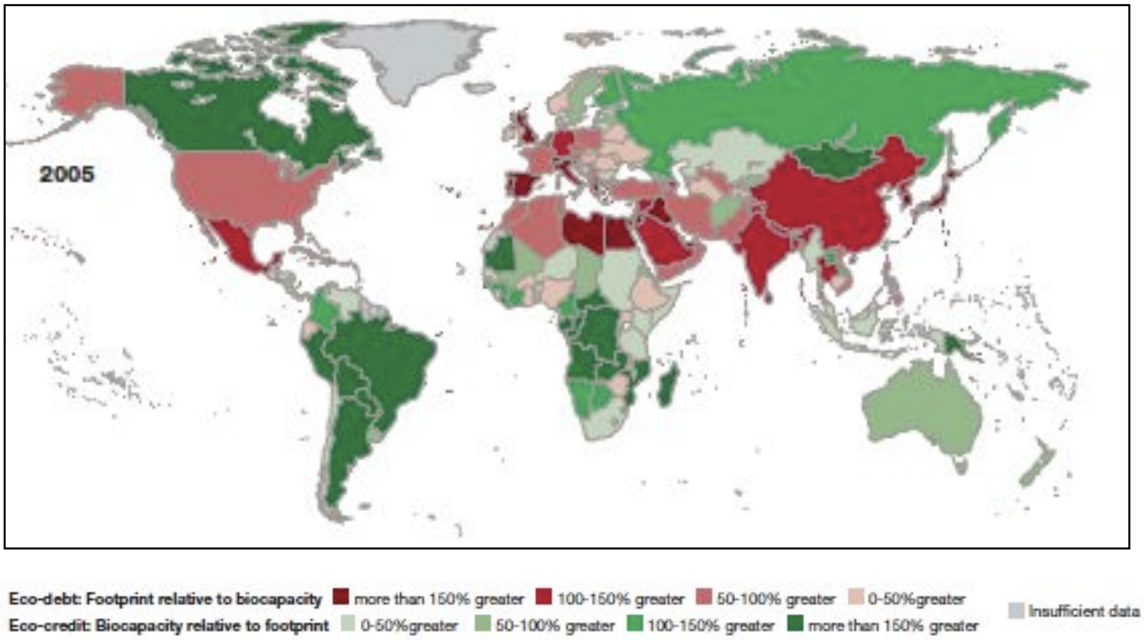


Figure 3. Trajectories for per capita ecological footprint (gha) toward a 10% biocapacity reserve in 2060: Equal sharing scenario



A possible, if not likely, objection to the equal sharing scenario is that it assumes equal sharing of biocapacity across the globe, without accounting for initial endowments of biocapacity. In climate change negotiations, developing countries have favored per capita accounting and equal sharing of the atmosphere, but wealthy countries have objected. (Kumar 2009; Posner and Sunstein 2008). For example, the 2008 Living Planet Report treats Canada, despite its relatively high per capita ecological footprint of 7.1 gha per person in 2005, as an ecological footprint creditor because its biocapacity would allow for an ecological footprint of 20 gha per Canadian. Figure 4 shows the global distribution of biocapacity creditor and debtor nations in 2005 (WWF 2008).

Figure 4. Biocapacity creditor and debtor nations in 2005.



Source: Living Planet Report (2008), p. 3.

An alternative set of trajectories for reducing ecological footprint could be based on a requirement that every country maintain a ten percent biocapacity reserve within its own territory. This might be termed the "balanced countries" scenario. Table 2 and Figures 5 and 6 show the data and ecological footprint reduction trajectories for the ten selected countries and the world total under the balanced countries scenario.

Table 2. Target per capita and total footprints: Balanced countries scenario

Country	2060 target total ecological footprint (million gha)	2060 target per capita ecological footprint (gha)
Brazil	1224.6	5.6
Canada	581.6	13.1
China	1071.9	0.8
Germany	141.4	2.0
India	397.2	0.2
Mexico	163.7	1.3
Namibia	16.2	4.5
Spain	51.3	1.0
United States	1341.9	3.3
Viet Nam	55.9	0.5
World	12240	1.3

Figure 5. Trajectories for total ecological footprint (million gha) toward a 10% biocapacity reserve in 2060: Equal sharing scenario

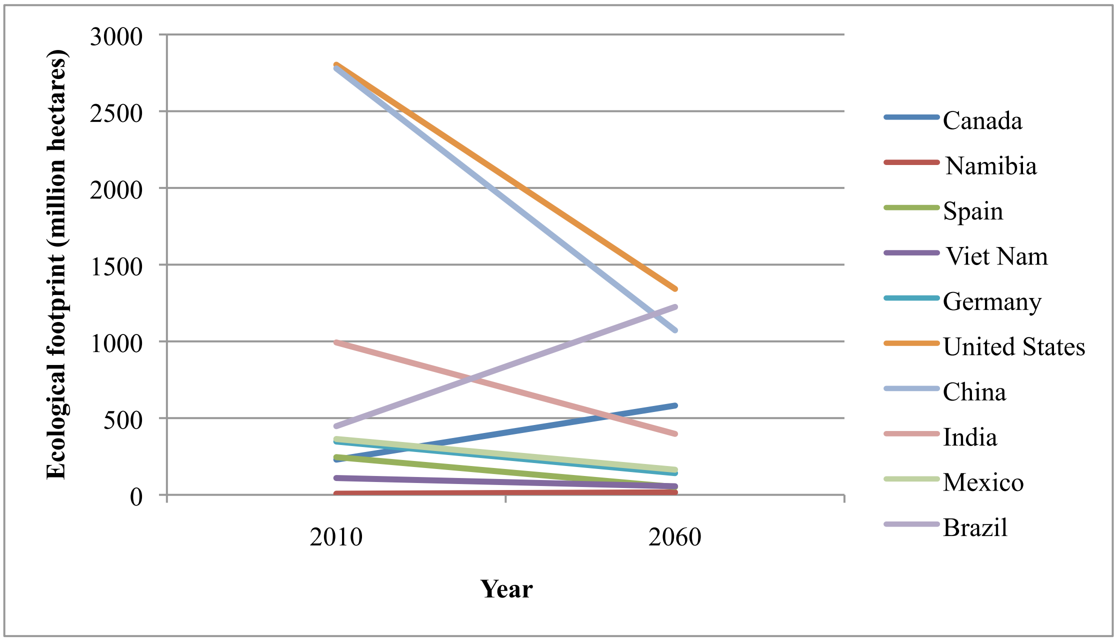
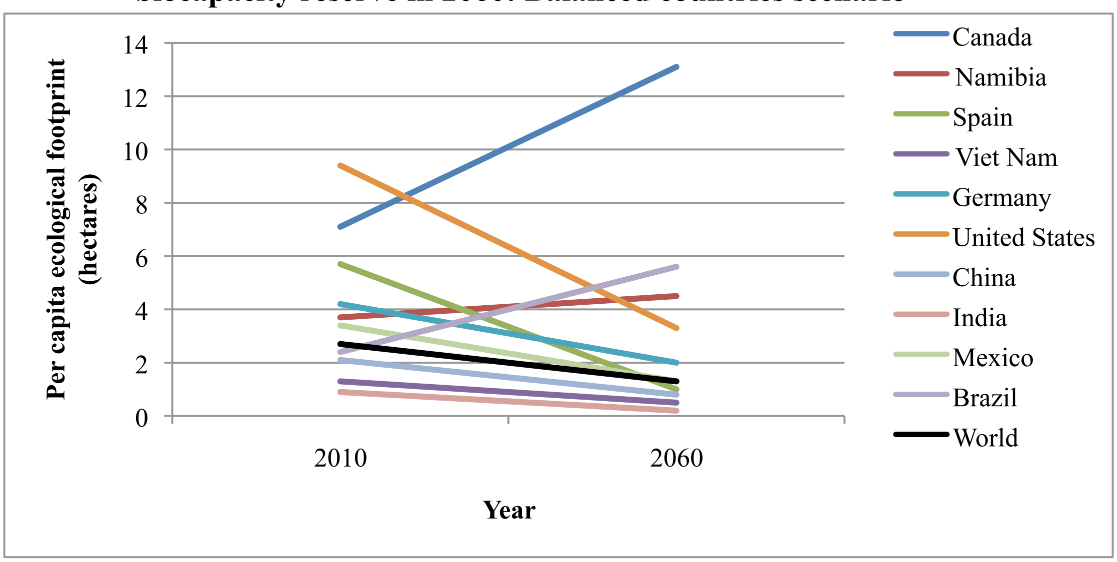


Figure 6. Trajectories for per capita ecological footprint (gha) toward a 10% biocapacity reserve in 2060: Balanced countries scenario



The equal sharing and balanced countries scenarios have competing elements of fairness. The equal sharing scenario treats all people in the world as equals, without regard to their proximity to life support resources. Countries like India and Viet Nam do relatively well under this scenario. However, it is weak on establishing incentives to provide for human communities within the local or regional carrying capacity, to control population growth and to ensure a global distribution of biocapacity reserves. The balanced countries scenario has the advantage of favoring a global distribution of biocapacity reserves but relies strongly on geopolitical boundaries that generally do not reflect ecological boundaries such as watersheds or species ranges (Van den Bergh et al. 1999) and that in too many cases reflect the spoils of conquest, war and oppression. Moreover, bioreserves in places like Canada and Brazil, which do well under the balanced countries scenario, have special global importance, for example in terms of global biodiversity and climate change mitigation. Therefore, preserving them benefits not only Canadians and Brazilians, but also the entire global community. Last, both the equal sharing and balanced countries scenarios leave unaddressed concerns over differences in the sensitivity of ecosystems, which might become important in considering national trajectories for reducing footprint, and even more so for any ecor trading that might take place among countries.

Addressing the full merits of these two scenarios would require a lengthy discussion. For example, one proposal that would certainly entail vigorous discussion would be to consider globally important assets like Canada's boreal forest as global assets excluded from ecor accounting. Suffice to say that country-specific trajectories toward a global ecological footprint that maintains a ten percent biocapacity reserve would likely be the result of difficult negotiations, with a result falling somewhere between the two scenarios. Under any scenario, however, "[t]o create the 'ecological space' for expansion in developing countries, the already wealthy must reduce their ecological footprints." (Rees 2002, 266). Notably, Mexico and Germany fare about the same under the two scenarios as analyzed here, and so might be well positioned, along with other countries with similar profiles, to lead such negotiations from a position of relative neutrality.

3. *Ecor accounts should be adjusted for total use of the Earth's ecological capacity, including both consumption and waste, compared to use allowing for a ten percent biocapacity reserve.*

Once ecors are allocated, countries would be required to stay at or below their ecological footprint trajectories on an annual basis. This would be true for both the transition period and the post-2060 period in which the biocapacity reserve is maintained. However, the Earth Reserve could allow ecor trading between countries, as long as the overall global footprint trajectory was maintained. In order for this ecor market to work, the ecor may have to be valued against national currencies, a task for which the Earth Reserve would need to play a central role in order to keep ecor creditor countries from holding out against ecor debtors. The incentives underlying the market would be somewhat unusual, in that conventional market dynamics, in which the reward to ecor sellers would be a monetary payment that would typically translate into greater consumption, and hence greater ecological footprint, would undermine the system. Therefore, the reward to ecor creditors could be in the form of expenditures targeted to enhancement of ecological integrity or future reductions in ecological footprint.

Another challenge in trading stems from the aggregate nature of ecological footprint, which accounts for many different kinds of demands for consumption and waste assimilation, distributed among many different kinds of ecosystems. (Wackernagel et al. 2002). Different types of demands on biocapacity and different types of ecosystems might not be substitutable (Van den Bergh 1999), which complicates trading of ecor based on an aggregated indicator like ecological footprint. One possible solution would be to disaggregate ecological footprint into its component demands and ecosystem types, as necessary to facilitate trading. Already, the Living Planet Report presents information on different wedges that make up countries' ecological footprints (WWF 2008), and Kitzes et al. (2009) propose research, discussed further below, that might help overcome the substitutability problem.

Some amount of borrowing against the future might also be permitted, but only in two situations. The first is the situation in which a clear showing is made of a delay in the time in which policies already implemented will yield expected ecological benefits. Similarly, borrowing might be possible for investments that contribute to ecological footprint in the short term but are shown with a high degree of certainty to lead to long-term reductions. Investments in green building, low-impact transportation systems and other green infrastructure or technology might require this kind of borrowing. However, special provisions would be needed to ensure that borrowing does not become the rule and that confidence in the expected ecological returns on the investments is high.

The annual settling of ecor accounts should include an annual updating of the population and biocapacity data on which the ecor accounts are based, as well as on the data and methods with which the ecological footprint or other indicator to which the ecor is pegged is based. The Earth Reserve should become the central global repository of this data and given the capacity, resources and authority to gather the necessary data efficiently. In fact of the mounting risk of social and ecological collapse due to human consumption patterns, the work of the Earth Reserve should be a high global priority for the 21st century.

4. *Failure to maintain a balanced ecor account should be subject to strong penalties.*

The global community should give the Earth Reserve or other appropriate institution clear authority, supported by an effective enforcement regime, to impose strong penalties on countries that exceed their ecor accounts. Penalties could include monetary sanctions or imposition of heavy ecological tariffs on goods and services from the offending country, along with rigorous plans for returning to a balanced ecor account. One task of the Earth Reserve could be to design and recommend penalties severe enough to counteract the excessive footprint triggering the penalty. Penalties could be devoted to ecosystem restoration, afforestation, reforestation, low impact technology development or procurement or other projects that tend to reduce the global human ecological footprint or improve global ecosystem integrity.

5. *The effect of the ecor should be to drive international transactions toward those with the least ecological impact.*

In some, if not most, cases, the establishment and enforcement of ecor accounts should favor local, bioregional provisioning of the human economy. In others, provisioning through international trade may be the most efficient outcome in terms of ecors. (WWF 2008). In yet others, and certainly in much of the developed world, avoided consumption and waste would provide the best means for respecting ecor limits. In this formulation of the ecor exchange system, the effect of ecors on consumption patterns is indirect. The ecor exchange would require countries, assisted by the Earth Reserve, to establish comprehensive systems to track ecological footprint, along with country-specific measures to rein in trade and consumption in order to respect their ecological footprint trajectories. The nature of those measures would be for each country to determine, based on their legal systems, environmental circumstances and other factors. These and other implications of the ecor are discussed further below.

6. *To complement the ecor exchange, internationally traded goods and services should be subject to surcharges or credits to reinforce countries' ecological footprint trajectories*

The Earth Reserve would be responsible for assessing and clearing all international transactions annually in order to administer the ecor exchange system. In order to help maintain international trade at or below the level at which total appropriation of ecological capacity leaves a ten percent biocapacity reserve, the Earth Reserve could impose surcharges or credits, in the currency of the importing country, on goods and services traded in international commerce. The purpose of these credits and surcharges would be to reflect ecological benefit or cost in the price of imports. Although these adjustments would apply only to imports, they would have to be made in light of detailed country-level and global information on total appropriation of ecological capacity, and on the non-adjusted price of individual goods and services. Thus, the Earth Reserve would have to account for countries' total ecological footprints as well as their trade-related footprints, and make ecor adjustments so as to steer trade to the level that results in the lowest total footprint. In essence, the Earth Reserve credit or surcharge would give goods and services an absolute advantage not based on price but on least use of ecological capacity. Consistent with the cap-and-trade element, the ecor would not automatically disfavor trade, and indeed it would favor consumption of a good or service through international trade if doing so would lead to a lower ecological footprint than obtaining it through domestic trade.

A recent study of the ecological footprint of two different Italian wines illustrates the kind of assessment required for this formulation of the ecor. (Niccolucci et al. 2008). Each of the wines examined in the study by Niccolucci et al. sold for between fourteen and eighteen euros. One was produced organically in a small-scale operation and the other using chemical fertilizers and pesticides in a relatively large-scale operation. The researchers looked at the ecological footprint broken down into four phases: the agricultural phase, the winery phase, the packing (i.e. bottling, corking and labeling) phase and the distribution phase. The ecological footprint accounted for labor by including a pro-rated ecological footprint per worker, using the average per capita ecological footprint in Italy. The ecological footprint for the distribution phase accounted for the average distance the wine traveled to the consumer and the transport method used, using actual shipping records. The footprint for organic wine, which the researchers deemed more sensitive than conventional wine to "natural variations," was calculated over six years to increase the accuracy of the results, although the authors concede six years may not be sufficient for statistically significant results. The ecological footprints were estimated at 1.12 gha per tonne (gha/t) for the organic wine and 2.19 gha/t for the conventional wine. Notably, the agricultural phase represented the greatest portion of the ecological footprint: 67% for organic wine and 76% for the conventional wine.

Niccolucci et al. (2008) note the relatively limited number of agricultural and industrial processes for which this type of footprint calculation has been done. Yet, this is precisely the kind of data analysis that the Earth Reserve would have to do, at least on a sectoral level, in order to make price adjustments on imports. In the case of the Niccolucci et al. study, a higher surcharge would be required for conventional wine than for organic wine. However, cast as an international trade mechanism, the surcharge would only apply to internationally traded wine, and the precise surcharge would have to account for the actual destination of the wine; the surcharge for wine shipped to France would be smaller, for example, than the surcharge for wine shipped to Japan.

Although the surcharge would apply only to internationally traded goods and services, it could only work if it also affected domestic consumption. This is why the Earth Reserve would have to account for ecological footprints of a country's non-traded goods and services, and not only imported goods and services. For example, if Italian organic wine consumed in California has a lower overall ecological footprint than comparable non-organic wine produced in California, even accounting for transport, then the adjustment should make the Italian wine cheaper than the California wine.

Data and other administrative demands necessary for administering these credits and surcharges could be significant. However, much of the necessary data likely is already collected by national and international organizations, including customs authorities, tax authorities, trade commissions and the United Nations Food and Agriculture Organization, the United Nations Statistics Division, and the International Energy Agency, and is already used in ecological footprint calculations. (Kitzes et al. 2009).

Challenges in adapting ecological indicators as references for the ecor

Ecological indicators other than ecological footprint might also have potential application as a reference indicator for the ecor. Candidates considered here include HANPP, MFA and a composite indicator based on a set of planetary boundaries. All of these indicators pose challenges in terms of measurement and application to a system for allocating global use of ecological capacity. The most notable issue regarding all of these indicators is that they would be used in reference to the ecor as aggregate measures (although the composite indicator based on planetary boundaries less so than the others). Aggregate measures potentially mask the heterogeneous nature of the myriad processes they represent and imply a degree of substitutability among those processes, and among different kinds of capital, that may not be realistic or useful. (Van Kooten and Bulte 1999; Van den Bergh 1999) (both applying this criticism to ecological footprint).

Ecological footprint

Ecological footprint is likely the indicator of human appropriation of ecological capacity with the broadest application to date. (Merkel 2003, 76-77; Kitzes et al. 2009). Wackernagel et al. (2005) define ecological footprint as

> how much of the annual regenerative capacity of the biosphere, expressed in mutually exclusive hectares of biologically productive land or sea area, is required to renew the resource throughput of a defined population in a given year—with the prevailing technology and resource management of that year. (Wackernagel et al. 2005, 4).

Consumption is categorized in terms of land area needed for "(*i*) growing crops for food, animal feed, fiber, oil, and rubber; (*ii*) grazing animals for meat, hides, wool, and milk; (*iii*) harvesting timber for wood, fiber, and fuel; (*iv*) marine and freshwater fishing; (*v*) accommodating infrastructure for housing, transportation, industrial production, and hydro-electric power; and (*vi*) burning fossil fuel." (Wackernagel et al. 2002, 9266-9267). Ecological footprint is usually measured in global hectares, units of fictional land area that have the average global productivity in terms of useable biomass. (Wackernagel et al. 2005, 6-7). Although the notion of fictional units of land, as opposed to real acres, is essential for ecological footprint to serve as a comprehensive ecological indicator, it has been criticized as implying "false concreteness" that may lead to confusion. (Van den Bergh 1999, 64). To partially addresses this concern, methods now exist for expressing ecological footprint in terms of land area of specific land types or even actual acres that better reflect reality. (Kitzes et al. 2009; Niccolucci et al. 2008).

The methodology for calculating ecological footprint has undergone continuous improvement. (Kitzes et al. 2009; Wackernagel et al. 2005). For example, a compound accounting method, in which aggregate data on consumption are re-distributed among individual instances of consumption, replaced the original, more error-prone component method, in which separate calculations of individual uses were estimated and then summed.[11] (Wackernagel et al. 2005). The lack of data, along with the difficulty in incorporating toxic pollutants, biodiversity effects and water use into ecological footprint calculations, may cause ecological footprint calculations to underestimate, or in some cases to overestimate, ecological impact. (Wackernagel et al. 2005; Haberl et al. 2001; Kitzes 2009).

Kitzes et al. (2009) recommend twenty-six research items for improving ecological footprint methodology, focusing on issues related to

- the quality, accuracy and completeness of source data;
- the use of standardized global hectares and actual hectares in different applications of ecological footprint and in time series measurements of footprint;
- specification of different land types used in ecological footprint calculations; inconsistencies between the "materials balance" and "input-output" methodologies for calculating the ecological footprint of internationally traded goods and services;

[11] To illustrate, the national ecological footprint for paper consumption is based on a single calculation using the total national production of paper, not on separate calculations of each use, for which data was unreliable and double counting was a concern. (Wackernagel et al. 2005, 6). Other concerns about double counting, for example that land may serve more than one purpose but is treated in ecological footprint calculations as serving only a single purpose, Van den Bergh 1999, seems to confuse the fictional land area used for ecological footprint with actual land area.

- apportionment of ecological footprint between importing and exporting countries;
- the inclusion of energy and greenhouse gas emissions in ecological footprint calculations, which currently do not account for greenhouse gases other than carbon dioxide or carbon dioxide emissions from land use change like deforestation;[12]
- treatment of water use, persistent toxic pollutants and biodiversity in ecological footprint calculations;
- consideration of present activities that will have a demand for ecological footprint primarily in the future; and
- harmonization of ecological footprint accounts and data with national or international economic and environmental accounting systems.

This is a significant research agenda, and much of it would apply to other indicators that might be used as a reference for the ecor. This research will enhance the suitability of the ecological footprint as a reference for the ecor or in other applications. The research list itself underscores the need for a well funded, highly skilled Earth Reserve.

Human appropriation of net primary productivity

Several notable efforts have been made to measure HANPP. (Vitousek et al. 1986; Imhoff 2004; Haberl et al. 2007a). Net primary production (NPP) is the net amount of carbon that plants fix through photosynthesis, after subtracting the energy used for their own respiration. It represents biomass energy available to various consumers, including humans, in ecosystems. (Haberl et al. 2007a). In the most recent effort by Haberl et al. (2007a), HANPP is defined as the difference between the potential NPP that would exist in the absence of humans and the net amount lost or gained due to humans through changes in productivity,[13] agriculture (crops and grazing), timber harvesting, and what Harberl et al. call infrastructure areas (e.g., urban areas). Id. Within this definition, HANPP includes two components: first, the difference between the potential NPP and the NPP actually available, after accounting for losses or gains of NPP due to land use changes caused by humans; and second, the NPP actually harvested.

[12] Because the ecological footprint attributed to the land needed to absorb carbon emissions accounts for about half of the current global ecological footprint, ecological footprint methodology is particularly sensitive to the methods for treating greenhouse gas emissions. (Kitzes et al. 2009).

[13] Land use changes and technology changes can either increase or decrease the productivity of land. Irrigation and fertilizers, for example, increase NPP. (Foley et al. 2007).

Haberl et al. (2007a) calculate potential NPP using a model, but potential NPP is a fiction that some might see as somewhat arbitrary. The HANPP calculated in the most prominent studies since the 1970s ranges from 2.6 to about 30 Petagrams (billion metric tonnes) of carbon per year (PgC/yr), or three to thirty-nine percent of total NPP. The most recent results indicate that HANPP represents between twenty and thirty percent of total potential NPP. (Haberl et al. 2007b). Haberl et al. (2007a) note disparities in the definitions that various researchers have given HANPP and attempt to resolve them. For example, they note that their definition of HANPP attributes HANPP to the place where the NPP was harvested or otherwise appropriated, whereas Imhoff et al. (2004) attributed it to the place of consumption. (Haberl et al. 2007a). Other key issues relate to the selection and relevance of the baseline for HANPP: HANPP compared to what level of NPP?

Haberl et al. have made an important contribution by sorting out methodological and definitional issues with respect to HANPP and, perhaps more importantly, by analyzing the spatial distribution HANPP at a high geographic resolution. (Foley et al. 2007). Nonetheless, all methods for calculating HANPP have issues regarding selection of databases, use of modeling,[14] and gap-filling methods where data are sparse, as is generally the case, for example, with estimates of HANPP due to livestock grazing. (Haberl et al. 2007b, 6). Moreover, additional issues remain in regard to the effect of HANPP on biodiversity, water and nutrient cycles, energy flows within food webs and other functions of ecosystems. As well, HANPP can be decreased by intensifying agricultural production, using irrigation, fertilizers, pesticides and selective breeding of crop species – practices that can exacerbate other environmental problems. (Foley et al. 2007; Haberl et al. 2007a). Finally, and perhaps most critically, questions regarding the use of NPP as a universal indicator must be taken seriously. As Foley et al. (2007) explain, "[u]sing [NPP] as a single 'common currency' of ecological systems, whether for corn and coconuts or beef and barley, assumes that all biological products are equivalent" and may mask the importance of local context.[15] (Foley et al. 2007, 12586).

[14] For example, because there is no historical record, Haberl et al. (2007a) use a dynamic global vegetation model to estimate the potential NPP.
[15] Wackernagel et al. (2005) suggest that ecological footprint is more sensitive than NPP "to the quality of the biomass generation and its usefulness to the human economy."

These unresolved issues, all of which are important both regionally and globally, complicate the determination of what limits on HANPP are required to avoid collapse – a determination that is implicit in ecological footprint calculations. (Haberl et al. 2001).

Material flow accounts

Material flow, or material and energy flow, accounting is a method for measuring the total extraction of biomass, sources of fossil fuel energy, metal ores, industrial minerals and bulk minerals used for construction during a given accounting period. (Krausmann et al. 2009; Haberl et al. 2004). As with balance of trade or payments, total extraction of resources must equal total use of extracted resources on a global basis, but individual countries can have imbalances due to trade. Krausmann et al. 2009. Although material flow accounts provide quantitative information on the total use of resources and are more comprehensive than measurements of HANPP, unlike ecological footprint, they have no inherent mechanism for determining when resource extraction has become unsustainable. Recent estimations of the total global material flow in all of the twentieth century (Krausmann et al. 2009) and of material flow accounts for the European Union against its trading partners (Giljum and Hubacek 2001) suggest some potential for MFA to be used in connection with the ecor concept. However, further work on determining when material flow accounts have surpassed a critical ecological threshold is needed for MFA to apply to the ecor concept as presented here.

Planetary boundaries

A recent study proposes the establishment of "planetary boundaries for estimating a safe operating space for humanity with respect to the functioning of the Earth system." (Rockström et al. 2009, 3). Rockström et al. propose nine different planetary boundaries and present initial estimates for seven of them. The boundaries relate to climate change, ocean acidification, stratospheric ozone, global nutrient cycles, atmospheric aerosol loading, freshwater use, land use change, biodiversity loss and chemical pollution. Id. Like ecological footprint, a composite indicator based on planetary boundaries has the advantage of having inherent ecological thresholds. In addition, use of a composite indicator might reduce concerns regarding use of aggregate indicators that assume substitutability and complementarity of different kinds of capital or processes. (Van den Bergh 1999). Any such gain would come with the loss in simplicity associated with a single aggregate indicator. However, if the planetary boundaries are mutually independent,[16] such that only one need be crossed to establish an ecologically unacceptable situation, administration of a composite indicator based on them in connection with the ecor might be relatively straightforward. Nonetheless, Rockström et al. acknowledge that their work, while supported by an impressive and diverse group of researchers, is preliminary and that most of the planetary boundaries proposed require substantial further development before a framework based on planetary boundaries is implemented. (Rockström et al. 2009). To function as a reference to the ecor concept, the composite indicator would also have to be translated from a global level through an allocation system that presumably would account for different national contributions to the impact that is measured against the various boundaries.

Implications of the ecor for economic growth and the valuation of money

The ecor represents a rejection of neo-classical economics in favor of ecological economics and implies a sharply increased role of government at all levels in regulating markets. Without question, the ecor would turn the current global economic order and institutions like the World Bank, the IMF and, especially, the WTO on their heads. The ecor implies across-the-board adjustment of markets and prices, subjugates economic growth to maintenance of a flourishing and prosperous global ecosphere and ties the value of money to a new form a scarcity – the increasingly apparent scarcity of global ecological capacity needed to support a human economy with long-term viability. Further, in contrast to current rules of the WTO, it requires rigorous assessment and consideration of means of production of goods and services in international trade and clearly favors trade that minimizes overall ecological impact.[17] Moreover, the ecor

[16] In fact, Rockström et al. (2009) discuss likely interactions among the boundaries.
[17] A recent WTO ruling on a dispute over a Brazilian import ban on retreaded tires illustrates the significant hurdles that must be overcome to justify environmental restrictions on trade. The WTO Appellate Body found that the import ban was "provisionally justified" as necessary to protect the environment, but that it was nonetheless discriminatory and a disguised restriction on international trade, and therefore in violation of WTO rules. (WTO 2008). The ruling reinforced prior rulings that found ruled against environmental restrictions in the United States on imports of

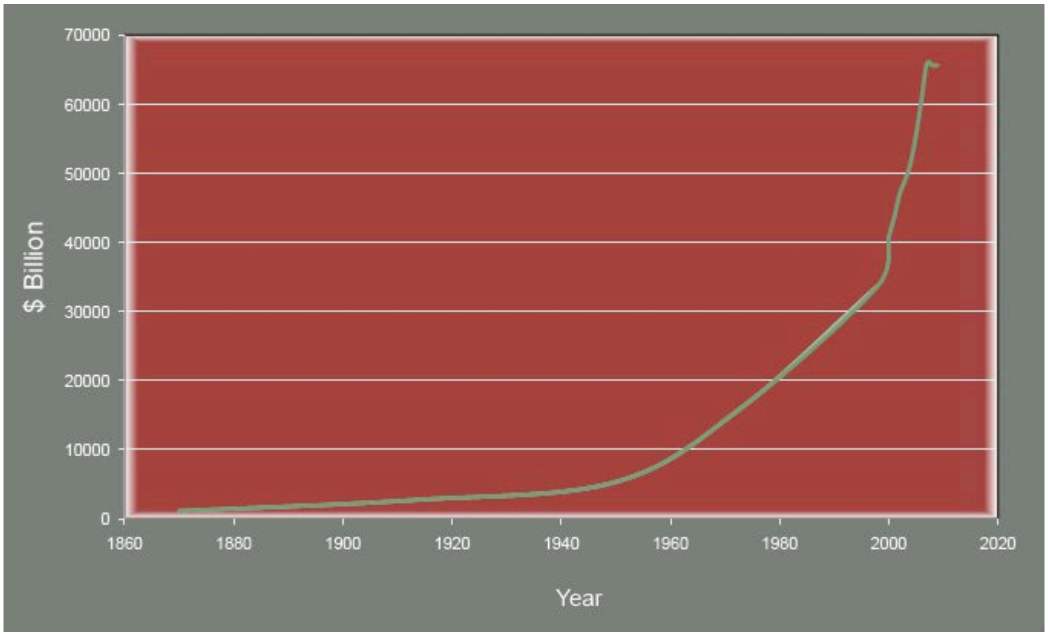
implies an overarching role for an international institution in regulating economic transactions, and therefore a significant and globally unprecedented incursion on national sovereignty.

The justification for this radical upheaval is that, given trends, nothing less will ensure that the human economy will respect the Earth's ecological limits. Solutions based on neo-classical economics to the challenges of climate change and other ecological problems are typically are built on an assumption of continued growth. For example, the Stern Review on the Economics of Climate Change assumed, consistent with the assumptions of the Intergovernmental Panel on Climate Change (IPCC), that the world economy will grow between 2 and 3 percent per year in the twenty-first century. (Stern 2006, 182).[18] Figure 6 shows estimated growth in the world economy from 1870 and 2009, and Figure 7 illustrates continued economic growth at two or three percent to 2100. Considering the urgent ecological crisis that growth up to 2009 has caused and the current global ecological footprint deficit, the graphs in Figure 7 present levels of growth that seem divorced from ecological reality.

Venezuelan gasoline, shrimp harvested without turtle excluder devices, and tuna fished without measures to limit dolphin by-catch, and Australian restrictions on importation of raw salmon contaminated with bacteria. (Daly and Farley 2004, 328).

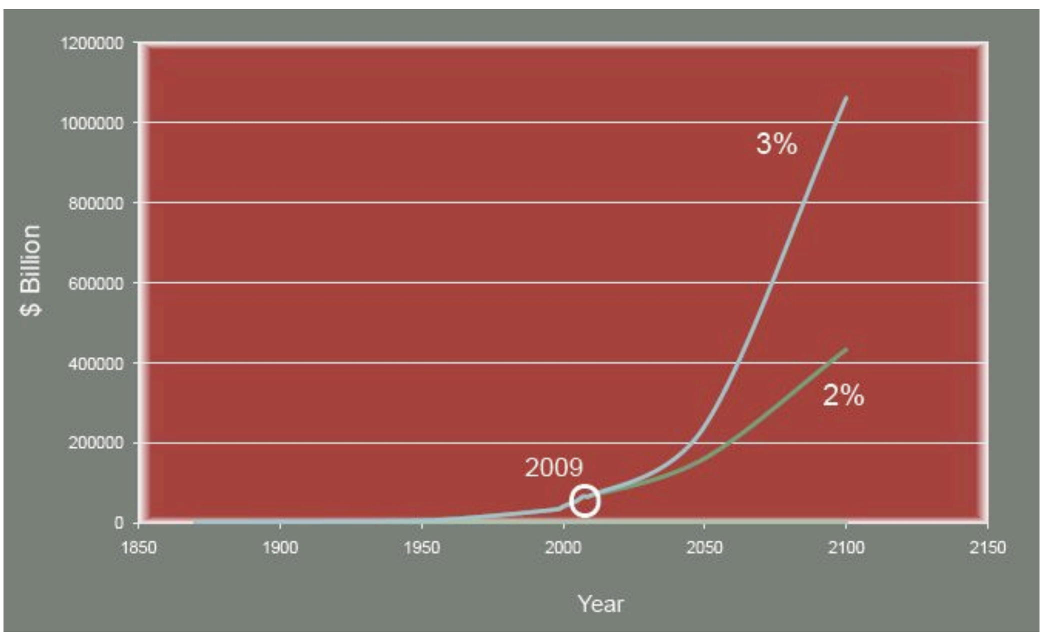
[18] The reasoning is that, "given that the growth rate of global GDP was around 2.9% per year on average between 1900 and 2000, and 3.9% between 1950 and 2000, projecting world growth to continue at between 2 and 3% per year (as in the IPCC SRES scenarios, for example) does not seem unreasonable." (Stern 2006, 182).

Figure 6. Growth in Gross World Product from 1870 to 2009



Source: OECD 2001; CIA 2009.

Figure 7. Projected Gross World Product to 2100 at 2% and 3% annual growth



Source: OECD 2001; CIA 2009; Stern 2006

For the growth depicted in Figure 7 to be possible, the material and energy throughput of the global economy would have to be drastically reduced, with increases in the efficiency of energy and material use far outpacing historical trends. Even at current levels of consumption, a ten-fold reduction in throughput of material resources in the economy is generally considered necessary to achieve sustainability. (Giljum and Hubacek 2001, 2). An economy de-materialized as necessary to achieve the growth depicted in Figure 7 defies imagination. (Victor 1991). It implies an assumption of vastly increased levels of individual wealth and consumption. Because money, from a systems perspective, is simply a mechanism of social exchange that carries with it an inherent right of access to the Earth's biocapacity, it is simply not credible that people with the overall monetary resources reflected in Figure 7 would not want to use their wealth in ways that in the aggregate would require vastly increased human appropriation of biocapacity measured in ecological footprint or otherwise.

The ecor will require the human community to adopt a different perspective on consumption, wealth and money, and a move away from the current insistence on economic growth as the societal cure-all. Unemployment concerns will have to be addressed through new kinds of intervention and not left largely to the vagaries of the market. Incentives for human progress and development will have to come not from an assumption that people only want more money, but from a common understanding that the ecological realities of our time require giving precedence to such ethical notions as fair sharing and the Golden Rule. Living a rich, meaningful life with the lowest possible impact will have to become what is most valued, not merely the greatest possible monetary wealth and consumption. The growth mythology is strong, as are market fundamentalism and the assumed right in much of the developed world of unfettered consumer choice. Replacing these ultimately destructive ideologies with a different and more ecologically realistic vision is the ecor's biggest challenge.

The ecor versus other options, like a carbon tariff

When Europe was considering carbon tariffs in 2008, one prominent criticism was that it would be a repeat of tariff wars in the 1920s and 1930s, in which tariffs purportedly designed on scientific and fairness criteria in order to balance trade effectively locked in the advantages of trade creditors over trade debtors. (Watson 2008; De Vegh 1943). Those tariffs wars and other attempts by individual countries to balance payments led, some argue, to an imbalance between creditor and debtor nations and contributed to the Great Depression and lead-up to World War II. (De Vegh 1943). The economic argument against carbon tariffs is that

> domestic prices … will adjust to offset any foreign competitive advantage arising from an economy-wide policy, … calculating exactly what the tariff should be is in fact very tricky, … and once politics enters the process there's no way to prevent the tariff being used for plain-old protectionist reasons that take it far beyond 'scientific' levels." (Watson 2008).

One key advantage of the ecor is that a global institution, not individual countries, would administer it, which would greatly alleviate if not eliminate fears of trade protectionism. The price for this neutrality is, of course, greater relinquishment of national sovereignty. Yet, the trend in Europe has been toward such a relinquishment of sovereignty when important ends were deemed at stake, and even in the United States, the great environmental awakening of the 1960s and 1970s led to relinquishment of state sovereignty over environmental protection in favor of federal environmental rules. As urban smog worsened and rivers like the Cuyahoga caught fire because of rising pollution, Americans broadly recognized, across political party lines, that federalization of environmental protection was necessary to keep individual states from placing economic advantage above environmental protections. In a world with a rising ecological deficit, why should this same reasoning not apply at the international level? The Earth Reserve, or something like it, is an institution, and the ecor an allocation tool, whose time has come.

Conclusion: Next steps for the ecor

The ecor as described here is a work in progress, requiring further development and refinement. Formulations of the ecor significantly different from what is proposed here might be possible. For example, the IMF is currently sending signals that it is preparing to establish an international currency other than the dollar as the global benchmark currency for trade, a move that could have strong support from the so-called BRIC countries (Brazil, Russia, India, China). (McKenna and Hoffman 2009; Xiaochuan 2009).[19] A move toward a new international currency would create an opportunity for

[19] Zhou Xiaochuan gave a speech at the People's Bank of China in early 2009, outlining the criteria for a new currency:

reviving the bancor proposal in a manner that is closer to Keynes' original conception of the bancor than is the ecor proposal here. It might also pave the way for an alternative formulation of the ecor that would use the scarcity of the Earth's ecological capacity available for human appropriation as the key element for valuing the ecor, much as the gold standard would have defined the bancor.

Is the ecor realistic? Perhaps not right away, regardless of how it is formulated. Many will see the implied relinquishment of national sovereignty as a non-starter, although the European experience in federalizing many environmental issues may provide at least a glimmer of possibility. But, the ecor also implies a radical re-thinking of a growth-insistent global economic regime and global adoption of "enough" rather than "more" as the shared goal for the economy. Other solutions, scenarios or recommendations that rely on a neo-classical economic framework, such as those in Stern (2006) and the IPCC reports, dominate current discussions. In addition, the current inequitable global distribution of ecological footprint creates a baseline situation in which the high impact, high material consumption countries will not easily agree to a framework and associated mechanisms that will inevitably require adjustments in behavior and consumption patterns that many currently see as sacrificial and unpleasant. It is doubtful that the ecor will pay for the American Dream of yore.

Yet, it is important to conceptualize and design institutional frameworks and mechanisms that will respond to the current ecological crisis in dramatic and radical ways. (Brown and Garver 2009). When the political and popular will materializes to fend off collapse, or to minimize its impacts, ideas born before their time could make the difference between a descent into social chaos and a hopeful new path toward the future.

> Theoretically, an international reserve currency should first be anchored to a stable benchmark and issued according to a clear set of rules, therefore to ensure orderly supply; second, its supply should be flexible enough to allow timely adjustment according to the changing demand; third, such adjustments should be disconnected from economic conditions and sovereign interests of any single country. The acceptance of credit-based national currencies as major international reserve currencies, as is the case in the current system, is a rare special case in history. The crisis again calls for creative reform of the existing international monetary system towards an international reserve currency with a stable value, rule-based issuance and manageable supply, so as to achieve the objective of safeguarding global economic and financial stability. (Xiaochuan 2009).

The ecor might be imagined along these lines, with ecological scarcity providing the benchmark.

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