COALITION:
BETWEEN GDP AND ECOLOGICAL FOOTPRINT

Stéphane Salaet Fernández
Economic Theory Department
ssalaet@ub.edu

ABSTRACT

Integrated Assessment Models (IAM) are the shape cost-benefit analysis has adopted when dealing with climate change. Despite their sophistication level, many criticisms have been raised against them[1]. Among these, reducing all relevant variables to monetary terms, the lack of accuracy about the parameters origin, and their uselessness in order to clarify conditions for cooperation.Thus, we try a slightly different approach. Recognizing the central role of GDP in industrial capital, we choose carbon footprint as its natural capital counterpart[2]. Then, we ask which would be the optimal output level for several country groups restricting their carbon footprint to biological capacity and, afterwards, which of these groups will produce if any should be saved as carbon reserves.

1. IAM (Integrated Assessment Model)

In a broad sense, an IAM is this kind of mathematical object

$$\max_{\{m^i\}_{i=1}^r} \sum_{t=0}^{T_{\max}} \sum_{i=1}^{r} \frac{w(y^i(t))}{(1+\rho)^t}$$

$$y^i_{BAU}(t) = f_1^i(y^i_{BAU}(t-1), t),\ i = 1,...,r$$

$$con(t) = \sum_{i=1}^{r} f_2^i(con(t-1), y^i_{BAU}(t-1), m^i(t))$$

$$\Delta T^i(t) = f_3^i(con(t), \Delta T^i(t-1), t),\ i = 1,...,r$$

$$y^i(t) = f_4^i(y^i_{BAU}(t), \Delta T^i(t), m^i(t-1), t),\ i = 1,...,r$$

$$ef^i(t) = f_5^i(y^i_{BAU}(t), m^i(t-1), t),\ i = 1,...,r$$

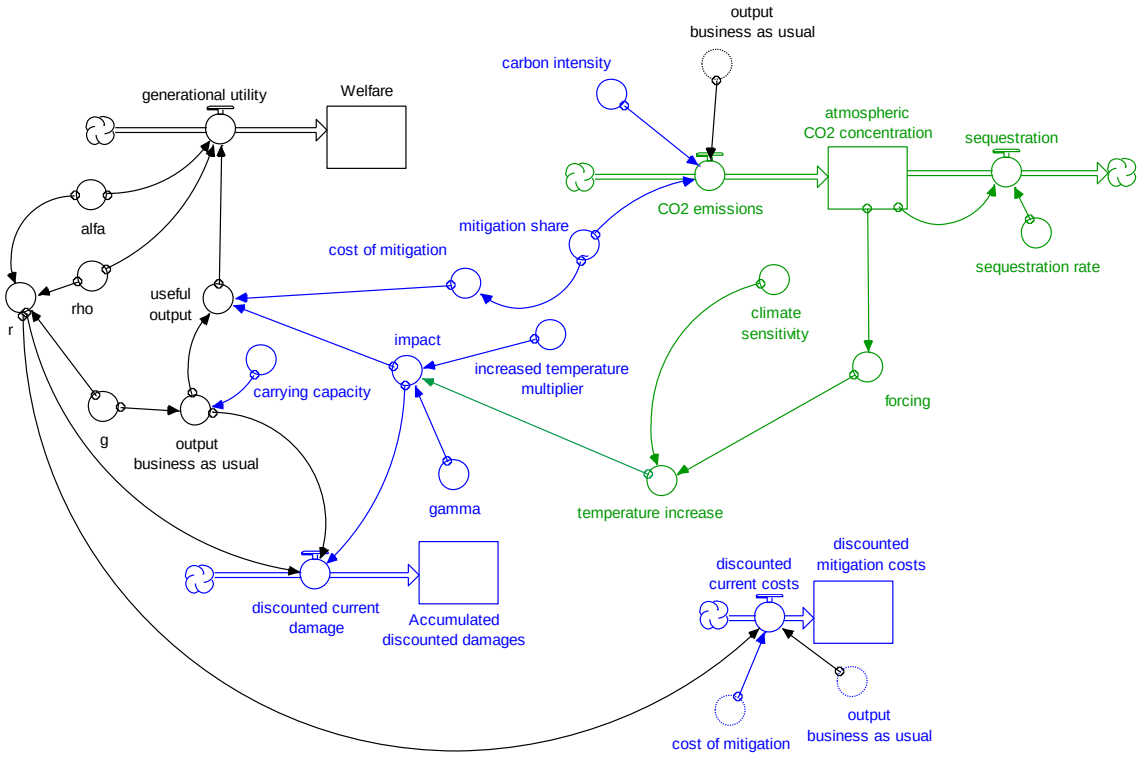
$$g^j\left(\{y^i(t)\}_{i=1}^r, \{\Delta^i T(t)\}_{i=1}^r, \{y^i_{BAU}(t)\}_{i=1}^r, con(t), \{m^i(t)\}_{i=1}^r, t\right) = 0,\ j = 1,...,J$$

$$h^k\left(\{y^i(t)\}_{i=1}^r, \{\Delta^i T(t)\}_{i=1}^r, \{y^i_{BAU}(t)\}_{i=1}^r, con(t), \{m^i(t)\}_{i=1}^r, t\right) \geq 0,\ k = 1,...,K$$

where $m^i(t)$ is the reduction in GHG emissions in region i at time t (from now

[1] See (DeCanio, 2003).
[2] See (Kitzes, Peller, Golfinger, & Wackernagel, 2007).

on we are going to represent each sequence of r variables by a vector with an analogous name), $y_{BAU}(t)$ is the output vector if there was no climate change, *con(t)*is the GHG concentration in the atmosphere, $\Delta T(t)$ is the temperature increase, $y(t)$ is income, $ef(t)$ is ecological footprint and g and h are several constraints. Solving this problem provides the optimal mitigation rates for each region. Following (Hope, 2006) these will be the European Union, the United States, Africa and Middle East, China and centrally planned, India and South East Asia, Latin America, Former Soviet Union and East Europe, other OECD nations.



i. Classical IAM schema.

There are many discussions surrounding the last schema. First, comparing human suffering with energy consumption in monetary terms is controversial[3]. This kind of objection is not new and, until now, cost-benefit defenders neither have been able to overcome it nor to devise the way to make the potential compensation effective.

On the other hand, there is no consensus about the true value of some essential parameters. Some of them, such as the pure discount rate, could depend on ethical basis[4] and are difficult, if not impossible, to gauge. This has been the key element in the heated debate surrounding Stern Review publication[5]. Others, for instance the climate sensitivity or the gamma coeffient associated with the impacts from global warming, cannot be measured due to the lack of historical data on the event. Many scientists and

[3] See Spash(2002), (Roca Jusmet & Martínez Alier, 1999).
[4] See Spash (2002) , Azar (1996) and Cline(1992).
[5] See Ackerman (2007), Nordhaus (2007) and Weitzman (2007).

economists fear these unknowns will not be resolve until it is too late for acting.

Those and other problems arising from IAM suggest exploring different ways to deal with climate change.

2. Tradeoff between GDP and Ecological footprint

Who should pay for the mitigation costs? This question has no easy answer. From a cost-benefit analysis it seems every region should account for their own mitigation policy m^i. But this point of view is opposed to those who believe that polluters should burden their contamination.

Taking into consideration the former criticisms we are going to fix a simple framework from which to look for an answer. Suppose a static model where the eight regions are committed to respecting the global carbon biocapacity C. Each region is characterised by its GDP_i and its carbon footprint C_i. The problem we are going to solve is

$$max \sum_{i=1}^{8} x_i \cdot GDP_i$$
$$\sum_{i=1}^{8} x_i \cdot C_i \leq C \, , x_i \in [0,1]$$

That is, the participation of the region in the global output will depend on both its GDP and its carbon footprint. Some comments must be made. Implicitly we are supposing there is a linear relation between GDP and carbon footprint in such a way that a 1-x decrease in GDP implies a 1-x decrease in Ci. That is not realistic and is adopted here only for the sake of simplicity.

The following table summarizes the results found

	GDP (E+06 $)	Carbon Footprint (global ha)	**Coalition**
European Union	9,24E+06	1112	1,00
The United States of America	10,20E+07	1664	1,00
Other OECD nations	6,93E+06	1054	1,00
Africa and the Middle East	3,45E+06	687	0,00
China and Centrally Planned Asia	5,99E+06	987	0,01
India and South East Asia	4,98E+06	331	1,00
Latin America	3,94E+06	318	1,00
Former Soviet Union and East Europe	2,82E+06	574	0,00

ii. GDP from (Hope, 2006), carbon footprint from (WWF International, 2006).

That means European Union, USA, India and South East Asia, Latin America and other OECD countries should produce at its maximum capacity while China and Centrally Planned Asia should reduce their output to just 1%. Former Soviet Union and East Europe and Africa and Middle East should stop their production. Of course this has not to be considered seriously but reflects interesting facts: former Soviet Union technologically obsolete output is worth less than its rich forests, oil-based Middle East economies are not sustainable and China has a long way to improve efficiency. And, what about high-income regions? The story is not so clear as it looks at first sight.

Stability

We only need a tiny 1% decrease in USA GDP to change radically the coalition shares.

	GDP (E+06 $)	Coalition
European Union	9,24E+06	1,00
The United States of America	1,01E+07	0,41
Other OECD nations	6,93E+06	1,00
Africa and the Middle East	3,45E+06	0,00
China and Centrally Planned Asia	5,99E+06	1,00
India and South East Asia	4,98E+06	1,00
Latin America	3,94E+06	1,00
Former Soviet Union and East Europe	2,82E+06	0,00

The above-mentioned coalition was not stable. We interpret this in the sense that USA is on a knife edge regarding its relation between GDP and carbon footprint. This is not good news to reach international agreements: if the biggest economy is pushing so strong on the biosphere there will be few opportunities for a fast switch towards sustainability.

Carbon reserve

The concept of carbon reserve could be interesting in the process of finding a solution. It is inherited from the fisheries management[6] and consists on leaving some regions free of fishing. It is supposed to protect the commons from overexploitation guaranteeing the activity survival through the preservation of one or more zones. In our model, we interpret the goal as

$$max \sum_{i=1}^{8} x_i \cdot GDP_i$$
$$\sum_{i=1}^{8} x_i \cdot C_i \leq C\,, x_i \in \{0,1\}$$

As it could be expected from what was obtained before the optimal coalition is formed by those regions which produced at their maximum capacity, European Union, USA, India and South East Asia, Latin America and other OECD countries leaving China outside the set.

This time the coalition is stable but only for shifts in USA GDP lower than 8%. Such a decrease would swap USA and China into the coalition of producers.

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[6] See (Hannon & Ruth, 2001) and (Hannon & Ruth, Modelling Dynamic Economic Systems).

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