Footprint Computation: Three Common Errors

Josep Mª Vegara
Director de l'IEMB

DT 1/2000

Documents de Treball és una publicació de l'Institut d'Estudis Metropolitans de Barcelona.

Footprint Computation: Three Common Errors[1]

ABSTRACT

Ecological footprint is increasingly used to evaluate ecological impacts. The paper emphasizes three common errors in the process of footprint computation.

First: the relevant impact is related to production levels, not only to consumption impact; even to compute this one it is necessary to use production impact; consumption can produce its own additional impact. It is very common to compute only consumption impact: this implies to underevaluate real impact.

Second: it is also very common to emphaize the additional impact of imports. What is relevant is net trade impact.

An input-output model allows to clarify these issues.

Third: the final comment is related to the utilization of the ratio footprint surface/factual surface; this ratio is equal to per capita footprint times the population density; as a result, one gets a paradox: the compact city is penalized.

Key words: ecological footprint, measurement, input-output

1. INTRODUCTION

As it is well known, the Ecological Footprint authors define this indicator as: «the ecologically productive territory (arable land, pastures, forests, sea and CO_2 absorption area) required to produce the resources used and to process the waste generated by a defined human population with a specific material standard of living, wherever this area may be.» (Rees; Wackernagel, 1996).

The concept is meaningful and it is increasingly used. However, some quantitative aspects related with its computation deserves some atention, specially, those related with consumption/production quantitative relationships.

[1] World Meeting «*Man and City. Towards a Human and Sustanaible Development*», Naples (Italy), september 2000

2. CONSUMPTION AND PRODUCTION

One of the central issues of this paper is the relation ship among footprint computation, consumption and production.

Let us consider two paradigmatic exemples.

Wackernagel states (Wackernagel, 1998), refering to Santiago´s ecological footprint estimation: «consumption is calculated by adding imports to national production and substracting exports»; this is, obviously a conceptual mistake. It is only true when there are no intermediate inputs.

Figures in (Wackernagel, 1998) show data relative to the equation:

Production + imports - exports = consumption

As I have already mentioned, this equation is only true when there is no intermediate consumption.

Some authors use household survey techniques (Simmons; Chambers, 1998). They compute footprint generated using a survey technique with questions related to consumption («Approximately ¿how far do members of your family drive each year? ¿What is the average fuel consumption of your main vehicle?»...)

Evidently they estimate only consumption direct impact and necessary production for consumption.

Let us analyse an extreme case related with production and consumption: let us consider steel sector. If we focus the analysis on consumption, its footprint will be zero because steel is not directly consumed: what is consumed are manufactured steel products: so, what is relevant for ecological footprint analysis is steel production (production, for exemple, contributes to CO_2 emissions, even if consumption is zero).

Some waste is directly connected to consumption, as is the case of domestic waste; in this case the «consumption approach» is correct.

Correct identification of impact vector (production or consumption) is crucial because to use consumption underestimates ecological footprint size and, in addition, comparisons are distorted.

3. PHYSICAL ACCOUNTING

Let us consider a simple but systematic physical accounting approach. In physical terms (2 goods case, closed economy) , the accounting takes the form:

$$X_1 = X_{11} + X_{12} + C_1$$
$$X_2 = X_{21} + X_{22} + C_2$$

Total production (X_1 and X_2) is used as an input for the rest of sectors (Xij) (some of them) and also for consumption (to simplify final demand composition, Di).The constant coeficient hypothesis gives us well known input/outpul model

$$X_1 - (a_{11}X_1 + a_{12}X_2) = D_1$$
$$X_2 - (a_{21}X_2 + a_{22}X_2) = D_2$$

and with an obvious matricial notation:

$$X - AX = D$$

and therefore: $X = (I - A)^{-1} D$

which is the well known relationship between consumption (final demand) and production.

4. AN EXAMPLE

Consider now a simple case with two impacts, so that it is necessary:

- land to produce goods (food,...)

- forest land to absorb CO_2

a) Goods production

$S = (S_1 \ S_2)$ is the vector where Sj is the land use per unit of **j** production.

Sf is total land necessary for production X.

$$S_f = SX = S (I - A)^{-1} D$$

See in *Annex 1* a numerical example

b) CO_2 absorption

Let **e** be the vector where the coefficients are the energy content per unit of production and **c** CO_2 emissions per energy unit. Coefficient **v** measures forest surface necessary to absorb a unit of CO_2. Total forest land, **Sv**, necessary to absorb total CO_2 emissions generated by production levels, X, is:

$$Sv = v*c*e*X$$
$$Sv = v*c*e*(I - A)^{-1} D$$

Therefore, total ecological footprint is: $S = S_f + Sv$

See a more elaborated analysis in (*Manresa and Sancho* , 1997)

5. INTERNATIONAL TRADE

Frequently, footprint is estimated for a closed economy and in a final step, the additional footprint generated by imports is added. The freudian message seems to be: as a matter of fact, the ecological footprint is even greater...

Obviously, the amount to add is the corresponding to Imports minus Exports.

6. SURFACE RATIOS

It is very common to compare total ecological footprint surface, He, with administrative surface, s. Let H be total population; therefore:

Surface ratio: $He/s = (He/H)*(H/s)$ where He/H is ecological footprint (in per capita terms) and H/s is population density. Therefore:

Surface ratio = ecological footprint (ratio)* population density

Identical ecological footprints (per capita defined) can generate very diferent surface ratios (see *Annex 2* and *Annex 3*) depending on population density. Compact cities (with high density population) will produce higher surface ratios than difuse cities. Surfaces ratio is, certainly, a misleading indicator.

7. CONCLUSION

Ecological footprint is a useful concept but its utilization require conceptually rigorous computation rules, compatible with empirical aproximations.

ANNEX 1

Let us considerer a simple numerical example.
A is the «technical» coeficients matrix
D is the consumption vector
X is the of production vector
S is the vector of productive land utilization for unit food production

$$A = \begin{bmatrix} 0{,}2 & 0{,}7 \\ 0{,}6 & 0{,}3 \end{bmatrix} \qquad S = \{1{,}0 \quad 2{,}0\} \qquad D = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$$

Leontieff inverse in: $(I - A)^{-1} = \begin{bmatrix} 5{,}0 & 5{,}0 \\ 4{,}28 & 5{,}71 \end{bmatrix}$

Production levels are: $X = (I - A)^{-1} D = \begin{pmatrix} 1.100 \\ 1.670 \end{pmatrix}$

Total production land utilization is: $S_1X_1 + S_2X_2 = 4.440$

X - AX = D + (Ex -Im)

therefore, $X = (I - A)^{-1}(D + (Ex - Im))$.

ANNEX 2

Local Ecological Footprints of Different Regions around the World

Author	Municip. or Region and year of calculation	Pop.	Extent in hectares	Footprint ha/cap	Footprint (ha)	Numbe times regi
William Rees, British Columbia University & Mathis Wackernagel, Anáhuac University, Xalapa.	Vancouver Region (Canada), 1991.	1.800.000	400.000	4,3	7.740.000	
Rod Simpson, Griffith University, Austràlia.	South-East Queensland Region 1991.	1.850.000	2.220.000	3,7	6.845.000	
Mathis Wackernagel, Anáhuac University, Xalapa.	Gran Santiago de Chile Region, 1992.	4.756.665	791.580	2,6	12.367.000	
Herbert Girardet, Middlesex University, U.K.	London Megacity, 1995.	7.000.000	159.000	2,8	19.700.000	
Mis. Lantsmewer, Munich City Council, Germany.	Munich, 1996.	1.300.000	31.000	3,5	4.550.000	
Maija Hakanen, Finnish Association of Local and Regional Authorities.	Mikkeli, Koulova, Tampere and Helsinki Regions, 1996.	32.000 a Mikkeli 22.000 a la resta de regions		2,6-3,6		
Anna Prat, Barcelona City Council.	City of Barcelona, 1996.	1.508.805	9.907	3-3,5	4.526.500 - 5.280.800	457

Source: Ferran Relea Ginés (director) & Anna Prat Noguer. *The Ecological Footprint of Barcelona. An approximation*. Municipality of Barcelona. September, 1998

ANNEX 3

Individual National Ecological Footprints

Country	Footprint in hectares/capita
Bangladesh	0,6
India	0,8
Pakistan	0,8
China	0,9
Ethiopia	1,0
Egypt	1,1
Indonesia	1,5
Jordan	1,6
Nigeria	1,7
Colombia	1,7
Turkey	2,0
Peru	2,0
Philippines	2,1
Mexico	2,3
Hungary	2,4
Costa Rica	2,6
Brazil	2,6
Thailand	2,7
South Africa	2,7
Venezuela	2,7
Malaysia	2,9
Hong Kong	3,0
Israel	3,3
Poland, Rep	3,4
Chile	3,6
Greece	4,1
Austria	4,1
Czech Rep	4,2
Spain	4,5
Italy	4,7
Argentina	4,7
United Kingdom	4,8
Germany	4,9
Netherlands	4,9
Korea, Rep	4,9
Switzerland	5,2
Belgium	5,3
Denmark	5,5
Portugal	5,6
Singapore	5,8
France	5,9
Sweden	6,1
Norway	6,2
Finland	6,2
Russian Federation	6,2
Ireland	6,5
Japan	7,0
Canada	7,2
Australia	8,2
United States	8,6
New Zealand	9,7