National Accounts in the Anthropocene: Hueting's environmental functions and environmentally Sustainable National Income: translation and relevance for ecosystem services

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Short communication

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Abstract

The UN System of National Accounts (SNA) calculates standard national income (NI) under the condition that owned capital is maintained. Roefie Hueting defined in 1969 environmental functions (state, stock) as the possible uses by humans of the environment. Their actual use (flow) nowadays are also called ecosystem services. Hueting defined in 1986 environmentally sustainable national income (eSNI) (flow) under the condition that the vital environmental functions are maintained for future generations. Then eΔ = NI – eSNI gives the national distance to environmental sustainability. Thus eΔ measures the level of ecosystem services concerning the part that infringes upon environmental sustainability, or the abusive part in the ecosystem services that are provided. This communication aspires at a translation of the terminologies by economist Hueting and ecologists in the research of ecosystem services.

Keywords

national accounts, national income, environmental sustainability, environmental functions, ecosystem services, eΔ = NI - eSNI, anthropocene, Jan Tinbergen, Roefie Hueting

Journal of Economic Literature (JEL) codes

E01 Measurement and Data on National Income and Product Accounts and Wealth • Environmental Accounts
Q50 Environmental Economics – General
Q01 Sustainable Development
O44 Environment and Growth
F64 Economic Impacts of Globalization – Environment
H23 Externalities • Redistributive Effects • Environmental Taxes and Subsidies
I30 Welfare, Well-Being, and Poverty – General
H43 Project Evaluation • Social Discount Rate
E61 Policy Objectives • Policy Designs and Consistency • Policy Coordination

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1. Introduction

In their new book, Hueting and De Boer (2019) provide bridges over time and between economics and ecology. Their book restates Hueting's definitions of environmental functions (1969, 1974, 1980) and environmentally Sustainable National Income (eSNI) (1986, 1992), with De Boer's close involvement in de derivation of environmental standards and the actual calculations. The authors mention that they have looked at their analysis afresh but they also point to the continuity in the analysis. Hueting (born 1929) basically developed these notions in 1965-1992, retired from CBS Statistics Netherlands in 1994, while the calculations were done in 1999-2008 by the IVM Institute for Environmental Studies at VU Amsterdam, though again with a rough estimate by Hueting & De Boer themselves for 2015. Hueting's thesis of 1974 created the foundation of environmental functions within (economic) scarcity, and the development of eSNI in 1986 provided the full link to the UN System of National Accounts (SNA). Their terminology differs from what has grown to be common within ecology. Their book's Section 6.12, quoted in the Appendix below, gives an overview of the terminology, such that "ecosystem services" (use, flow) are identical to the *use* (flow) of environmental functions (state, stock).

Braat & De Groot (2012) have an early reference to Hueting 1970 in Dutch and not 1969 in English. Braat (2014a) gives a history of the concept of ecosystem services that includes economist David Pearce and biologist Dolf de Groot but doesn't mention economist Hueting. In a presentation Braat (2014b, minute 8:20-9:30) clarifies:

> "(...) When Dolf [de Groot] and I started in the eighties on this [topic], actually in the late seventies, the term that was used for ecosystem services - before Paul Ehrlich launched the term ["ecosystem services"] - was "functions of the natural environment" or "functions of nature", but we meant the same. When TEEB [The Economics of Ecosystems and Biodiversity, 2010] came out and the ecosystem services concept had been evolved, then we had to find a place for the concept of a function. Now there was [such a place] in ecology, because the textbooks already had a term "function" which was strictly ecological. [[1]] So, we got rid of our old language, and said: What we mean is the flow of activities within the ecosystem, when we say "function". If that flow of energy or matter is used by people and interacted with by people then we are talking about "services". So, the services became a sort of linking pin to the ecological world and the economic social world. [[2]] (...)"

Thus both Hueting and Braat agree that ecosystem services are flows relevant for humans, and Hueting is clearer than Braat in the video in distinguishing between de functions (state, stock) and their use (flow). The link between ecosystem services and Hueting's work thus basically should be clear. Learning a language however requires some practice, this also holds for ecologists reading economist Hueting's work, and thus this communication ought to be useful. Since the late seventies ecologists have used their own language to link up to economcis, and they must master the definitions by economist Hueting to understand his work on the link to the System of National Accounts and the concept of environmentally Sustainable National Income (eSNI).

It is important to be aware that there is an overall "Tinbergen & Hueting approach", in which Hueting looks at statistics (the past) and Tinbergen looks at planning (the future), see Colignatus (2019a, 2019b). Tinbergen (1903-1994), the first laureate in the Nobelprize in economics, fully supported Hueting's analysis, and the joint Tinbergen & Hueting (1991) article has been reprinted as an appendix in Hueting & De Boer (2019).

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[1] For example, ants that allow plants to grow better, without necessarily any consequences for humanity.

[2] The word "became" might suggest that the result is new but Braat (personal communication) only intends to express an existing understanding about this linking pin. See Hueting (1974, 1980) for a historical review of this understanding. Hueting (1969, 1974, 1980) is innovative for economics by providing a stricter definition of environmental functions (namely: possible uses by people) and linking those functions to scarcity, and thus showing beyond doubt that scarce environmental functions *by definition* belong to the subject matter of economics.

It is also important to mention a disclaimer here. The author of this present communication is an econometrician and teacher of mathematics, and has no knowledge about ecology and environment. He has supported Hueting and De Boer in finalising their book by providing suggestions for structure and didactics. Thus, this present text is not intended as a book review by someone familiar with both economics and ecology, and it is actually recommended that such review comes about by someone with that knowledge.

Colignatus (2019a) looks at the reception of the Tinbergen & Hueting approach, taking the meta-level of Political Economy. From Section 1.10 of Colignatus (2019a), some small models in mathematical economics can be quoted in this communication, to highlight the conceptual links we are currently interested in. The next section quotes the "managed" system that is recorded in the System of National Accounts (SNA) with the standard measure of national income (NI). The subsequent section quotes the "not-managed" system that still provides the ecosystem services by the environmental functions. The third section quotes the link between these two sections means of eSNI.

2. A standard model for the economy and national accounts

The managed system that is recorded in the SNA may be described by a dynamic Von Neumann model, in a slight variation upon the Leontief-Solow programming model summarised by Takayama (1974:522-527). We distinguish human activity levels (n-vectors) and goods and services (m-vectors). Human economic activity x requires intermediate inputs $A.x$ and has outputs $H.x$ in terms of flows, requires capital $B.x \leq k$ in terms of stocks, and requires $L.x \leq \ell$ of labour. Final demand are consumption c and investment i. The capital stock of the next period consists of current capital plus investments minus depreciation. The (square) identity matrix is I, and a diagonal matrix with depreciation rates is D. This gives these inequalities:

$A.x + c + i \leq H.x$	intermediate and final output
$L.x \leq \ell$	labour
$B.x \leq k$	capital requirement
$k[t + 1] = (I - D).k + i$	capital next period

If capital would have balanced growth factor $1 + g$ then there is a direct relation between c and x, that with full rank solves with a generalised inverse.

$$i = (g\ I + D).B.x$$
$$c \leq (H - A - (g\ I + D).B).x$$
$$x \geq (C'.C)^{-1}\ .C'.c \quad \text{with } C = H - A - (g\ I + D).B$$

With prices p for goods and services and wages w, we find value added VA or standard national income NI or GDP, and capital income Z and capital return r.

$$VA = p'.(c + i) = p'.(H - A).x$$
$$VA = Z + w'.L.x$$
$$r = Z / p'.k$$

The definition of *income* requires that the capital stock is left intact. One doesn't live from the proceeds of selling one's capital. The above calculation of VA thus assumes that $k[t + 1] \geq k$ or for balanced growth $g \geq 0$. A weaker condition is that monetary capital is kept intact, and then a negative value of Z clearly is subtracted from income.

For the above, the Von Neumann model has been chosen to allow for the phenomenon that some environmental functions (state, stock) and their use (ecosystem services) have already been included in the SNA and national income accounting. Consider for example the emissions trading systems. The criterion is not economic property law itself, since economic property (parts of the environment subject to ownership) can have environmental functions

that are not managed. Such phenomena can be included in the accounting of ecosystem services (use of environmental functions). For the latter the Von Neumann model seems better. Thus, it seems better to use this model in both cases.

3. The link between economy and ecology

Ecology is the study of ecosystems, and ecosystems are all physical surroundings. Only part is measured as relevant for humanity and this part is called the "environment". It is the environment that provides for environmental functions (possible uses). Let us consider resources f ("natural capital") (μ-vector). The environmental functions of an environmental resource j (e.g. water), with level f_j (stock, state), are the possible uses $\imath$ (iot), for $\imath = 1, ..., n_j$, having actual usage u_{ij} (flow). Take $\lambda = n_1 + ... + n_\mu$. The uses or ecosystem services thus give a λ-vector. The resources generate an availability for use $F.f$. Human activity x uses $M.x$ and produces $P.x$ as categorised by those functions. The net use has matrix $N = M - P$. (Observe that the competition between functions may make $F = F[t]$ and $N = N[t]$ much more period-dependent than production technologies A, H and B above.) With λ rows and μ columns, there may well exist a generalised inverse $(F'.F)^{-1}.F'$ that allows the back-calculation from net use to the reduction of resources. Otherwise a more complex calculation must be made. The resource level of the next period consists of the begin value plus the regeneration minus the actual use at the resource level.

$M.x \le P.x + F.f$ or $N.x \le F.f$	μ resources allow λ uses
$(F'.F)^{-1}.F'.N.x \le f$	translating above x into resource use
$f[t+1] = (I + R).f - (F'.F)^{-1}.F'.N.x$	regenerative R

We assume that humanity triggers the system to some regeneration. If humanity would not exist then $x = 0$ and also $R = 0$. The resources can find a stable minimum at regeneration when $f[t+1] = f = f_R$. Substitution gives an expression for the activity level x_R.

$R.f_R = (F'.F)^{-1}.F'.N.x_R$	potentially solvable for x_R

When f contains resources that still may support economic production for at least some decades before it collapses, the distance $f - f_R$ is quite large, and a reduction of human activity to only the regenerative capacity of the environment would be overly restrictive compared to requirements for environmental sustainability. The case is only mentioned for comparison.

For the valuation of these ecosystem services, prices are difficult to obtain. Hueting (1974, 1980) looked at methods of contingent valuation and such, and judged that those were inadequate for the ecological challenge. His practical approach to an unsolvable problem came in 1986 with the vertical demand curve.

4. The link from ecology back to national accounting (eSNI)

Due to considerations of scarcity, the economy consists of both production (section 2) and environment (section 3) and thus we must revise national accounting. Hueting & De Boer (2019) reason from the environmental functions and their use (or the ecosystem services) to the derivation of standards on the resources, as f_e, where the subscript stands for environmental sustainability. This is similar to Rockström (2018) but now is linked to the economy and national accounting. Current production is so far removed from the standards that those will be binding, so that the inequality becomes an equality. The level of resources f then would gradually reduce to the constant value $f[t+1] = f = f_c$.

$M.x_e = P.x_e + F.f_e$ and $x \le x_e$	standard f_e gives x_e
$x_e = (N'.N)^{-1}.N'.F.f_e$	restriction on NI
$f[t+1] = (I + R).f - f_e$	
$R.f_c = f_e$	$f[t+1] = f = f_c$.

Subsequently, there will be shadow prices and wages, giving value added VA_e, called environmentally Sustainable National Income (eSNI). In the present example with the Von Neumann model with fixed coefficients, the lower level of production would generate unemployment. Hueting & De Boer (2019) rely upon a model with substitution, that maintains employment. The shadow prices are also generated from demand equations not discussed here. When the labour income quote LIQ = $w'.L.x$ / VA would be kept the same, then $w_e'.L_e.x_e$ = LIQ VA_e, and Z_e = (1 – LIQ) VA_e.

$VA_e = p_e'.(c_e + i_e) = p_e'.(H - A).x_e$ eSNI
$VA_e = Z_e + w_e'.L_e.x_e$
$r_e = Z_e / p_e'.k$

Subsequently eΔ = VA – VA_e = NI – eSNI = GDP – eGDP gives the distance to environmental sustainability. This is the key statistical figure that can be presented to policy makers who are familiar with the concept of national income. In the calculation NI = eSNI + eΔ the total value is kept the same, but a distinction is made between proper income eSNI (keeping the environment intact) and costs eΔ (living above our means, taking resources from future generations).

5. Conclusion

The scheme of calculating a national income can be used for environmental costs, i.e. monetary values for the environmental functions and their use (ecosystem services). This approach means that NI itself is maintained and we look at the distance eΔ = NI – eSNI. For ecosystem services it may suffice to look at their causes and effects in real variables, as is done in section 3, and there would be no inherent need to find monetary values for aggregate terms. If one has the explicit purpose to develop such valuation, then this communication (and notably section 4) highlights the approach by Tinbergen and Hueting (1991) and its restatement and the proof of concept presented by Hueting & De Boer (2019). This communication thus looks only at the translation from the angle from national accounting, and how this would be relevant for studies in ecosystem services. To facilitate an easier bridge in the terminology, it is advisable to use both terms “ecosystem services” and “use of environmental functions” interchangeably, so that their identical meaning is clear.

I have had no intention here to look at how other authors perhaps are approaching such issues. I do also not have the intention to review the Hueting & De Boer (2019) book, since this would be for a reviewer with a background in ecology and economics. In my perception, Hueting & De Boer (2019) is a fresh review of an important approach for researchers working in the field of ecosystem services. Looking at ecosystem services means looking at human use, and thus quickly involves economics, and one would require this analysis as part in the economic analysis. The book fits the aims [3] of the journal “Ecosystem Services” and it is recommended that it receives a book review in this journal.

6. Appendix. Section 6.12 in Hueting & De Boer (2019): Natural capital and ecosystem services

(Quote of Section 6.12 in Hueting & De Boer (2019), with kind permission by the authors. Their references are not included in the references of this communication.)

Economic theory distinguishes capital (stock, state) and income (flow, use). Capital (a stock) associates with investments (a flow), and both of these pertain to the same kind of commodities (e.g. machines). In the same manner, an environmental function (a state variable, to be transferred to next period or generation) associates with the actual use of the function (a flow).

[3] https://www.sciencedirect.com/journal/ecosystem-services/about/aims-and-scope

Hueting (1967, 1969a, 1974a, 1980) developed his concepts and analysis at a time when the terms “capital” and “services” had a well-formulated meaning in the System of National Accounts (SNA), namely for human-made goods and human-provided services. Hueting used the terms of “natural resources” and new phrases like “not-human-made physical surroundings” and “possible uses” c.q. “environmental functions” to allow a clear reasoning about the relationship between production as defined in the SNA and the environment, see for example Hueting (1974a, 1980:167 footnote). [4] This was also recognised in the recommendations for an UNEP award. [5]

Other authors have preferred later not to introduce new terms but to extend the meaning of the existing terms of *capital* and *services*, see Ahmad et al. (eds) (1989), Pearce et al. (1989:3), Pearce & Atkinson (1993) and Hamilton (1994). In their view, the natural resources including ecosystems, and their environmental functions (possible uses, with their capacity depending upon the resource level and composition), can be seen as items of *“natural capital”* (stocks, states). The use (flow) of environmental functions, relevant for income accounting, can also be seen as *“(ecosystem) services”.* What has been identified as vital environmental functions are called elsewhere “critical natural capital”. **Table 1** gives an overview of the terminology.

	State variable	*Flow variable*
System of National Accounts (SNA)	Capital	Goods and services, national income
Environment, in this book	Natural resources, (vital) environmental functions	Use of environmental functions, environmentally Sustainable National Income
Environment, “capital approach” still not in the SNA	(Critical) natural capital	Ecosystem services

Table 1. Terminology in the literature

The reference in the literature to “ecosystems services” caused Hueting et al. (1998a) to distinguish between services and ‘services’: "Environmental functions are defined as possible uses of our natural, biophysical surroundings that are useful for humans. Uses can be either passive or direct and practical. The 'services' of environmental functions are defined as their possibilities or potential to be used by humans for whatever end. Some functions can be conceived as consumption goods, others as capital goods." For example, the value of a fish in the shop differs from the value of a fish in the water.

The World Bank (at some distance of SNA) has tended to refer to natural capital while simultaneously looking at (genuine) savings and depletion, see Section [...] on comparisons. An early reference to the distinction between produced, human, natural and social capital is O’Connor et al. (1995). A critical discussion is by Hueting and Reijnders (2004a).

The methods have an underlying structural identity and a quite different practical implementation. For example World Bank (2006:123) provides this explanation (though beware that income is not the same as the change in wealth):

> “Consistent with Hicks’s notion of income (Hicks 1946), sustainability requires nondecreasing levels of capital stock over time or, at the level of the individual, nondecreasing per capita capital stock. Indicators of sustainability could be based on

[4] In only this single statement, Hueting (1974a, 1980:127) uses the term “services of the environment” but without clarification whether this concerns use or potential use: “After all, the whole of production depends on the services of the environment. This well-known fact (...) does not lead to special individual behaviour as long as the functions are available to a sufficient degree.”

[5] http://www.sni-hueting.info/EN/Others/2019-05-02-Tinbergen-1990-UNEP-Sasakawa-Hueting.pdf

either the value of total assets every period, or by the change in wealth and the consumption of capital (depreciation) in the conventional national accounts."

Authors who recognise the identical meanings in **Table 1** are e.g. UN SEEA (2003) quoted in Section [...] and El Serafy (1998) and El Serafy (2013:5) quoted in Section [...] Herman Daly (see page [...]) has the comment that the calculation of income requires that capital is kept intact, so that income already would be sustainable by itself, and so that "sustainable national income" is a pleonasm, that is, if one approaches the issue from the angle of "capital theory". In Hueting's terminology it is no pleonasm, since capital belongs to SNA, and sustainability is a condition imposed from the environment.

At the fundamental level of economic theory, with the methods of accounting for capital and income, this book thus doesn't differ from the method used at the World Bank. We maintain the terminology of Hueting (1974a, 1980) not only for comparison with our earlier work but also for the same reasons of clarity. When we speak about capital and services then these would be recognised in the SNA; and when we speak about resources and functions and their use then they may not be recognised in the SNA.

Apart from theory there are relevant practical differences. A weak point of the World Bank "capital approach" is the reliance upon indicators instead of the use of a full-fledged model that describes the relationship between the economy and the environment. Also, there is often a lack of environmental standards to judge the level of such indicators. The "capital approach" tends to require that natural capital is valued in terms of money as well, which tends to come with tedious questions, while the approach of environmentally sustainable national income (eSNI), discussed below, is parsimonious in its requirements.

eSNI was part of the official Dutch national strategy of sustainable development for Johannesburg 2002, see Ministry of VROM (2002). The cabinet instructed the national planning bureaus to continue with the research on the indicators for sustainable development. eSNI obviously is an indicator too. Subsequently, the World Bank "capital approach" was adopted by the new generation of researchers at CBS Statistics Netherlands in the Dutch "sustainability monitor", see CBS, CPB, MNP, SCP (2009). Later, by advice of CBS, also the Conference of European Statisticians (CES, 2013) adopted this approach. Both CBS et al. (2009) and CES (2013) mention eSNI but refer to Hueting (1974, 1980), in which eSNI is not mentioned since it was introduced by Hueting (1986b). This gives the impression that the new generation of researchers at CBS did not study both thesis and eSNI.

While UN SEEA and El Serafy alerted economic researchers to the issue of terminology, there was the remarkable development that various researchers were not aware of it. For example, CBS et al. (2009) present the "capital approach" as alternative to eSNI, so that the new generation may not be aware that the same economic theory is being used. The practical difference concerns the implementation and calculation of eSNI.

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