Economic perspectives

The impact of Scotland's economy on the environment: a note on input-output and Ecological Footprint analysis

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Abstract

Several recent papers examining the impact of the Scottish and Jersey economy on the environment have criticised the Ecological Footprint (EF) method and have suggested the use of input-output (IO) analysis instead (McGregor et al., 2004a; McGregor et al., 2004b; Ferguson et al., 2004; Allan et al., 2004). It is argued that "IO can be used to provide a coherent and practical alternative method to the Ecological Footprint of locating the responsibility and source of resource use and waste/pollution" (Allan et al., 2004) and several aspects of the EF methodology are criticised specifically. In this paper we reply to these critiques and discuss the scope and limitations of both the NCLAS as well as the Ecological Footprint. We argue that EF and IO are complementary methods that can be combined in a meaningful way. We suggest a way forward that helps to improve the scientific understanding of key sustainable development issues.

Introduction

Input-output analysis (IO) is a well-established method (Leontief, 1966) and its extension by environmental issues in order to consequently attribute resource flows, pollutant emissions and other environmental pressure indicators to final consumption has been taught and practiced for several decades (e.g. Leontief, 1970; Miller and Blair, 1985). Furthermore, several studies have applied IO analysis to calculate the Ecological Footprints of nations and regions (Bicknell et al., 1998; Lenzen and Murray, 2001; Ferng, 2001; Ferng, 2002; McDonald and Patterson, 2004).

Several recent papers (McGregor et al., 2004a; McGregor et al., 2004b; Ferguson et al., 2004; Allan et al., 2004)[1] argue

that input-output analysis is a preferred alternative to the Ecological Footprint analysis also being used in Scotland (BFF, 2004). The project undertaken by the Oxford based consultancy Best Foot Forward established the Ecological Footprint of Scotland for the first time. Presently, a further EF study is being undertaken in Scotland, managed by WWF-Scotland, in partnership with North Lanarkshire Partnership and Aberdeenshire County Council, with the research component being undertaken by the Stockholm Environment Institute (SEI), based in York. In this study a hybrid approach of input-output and Ecological Footprint analysis is being employed that has been developed and applied in the 'Reducing Wales' Footprint' project (Barrett et al., 2005; Wiedmann and Barrett, 2005).

It is obvious that the impact of economic activities on the environment are complex. To try and understand the impact of economic and environment interactions and in order to be practicable, simplified models have to be used. Currently, environmentally extended input-output analysis as well as the Ecological Footprint methodology play a major role in understanding these interactions and in offering policy makers and the general public some guidance on the ways to improve both the economy and the environment. The main driver in this process is to try and make development sustainable in the early years of this millennium.

Reply to criticisms of ecological footprinting Whilst the exploration of alternative methodologies to describe the environmental burden of economic development are to be welcomed without reservation, the method of the Ecological Footprint has been negatively criticised. The three criticisms of the Ecological Footprint raised in the papers by McGregor et al. can be identified as conceptual, data requirements and the measurement unit (standardised global hectares).

a. The conceptual issue

McGregor et al. (2004) make two conceptual criticisms of the Ecological Footprint. First, they argue that the Ecological Footprint implies that the "consumption in one legal jurisdiction is held responsible for environmental damage that occurs in some other jurisdiction". Second, it is argued that "a country's responsibility usually apply to its own pollutant generation or resource use" (McGregor et al., 2004a, p.30). From a legal perspective this second statement is true if it comes to the implementation of pollution control measures from local pollution sources. The jurisdiction of a country has to ensure that national and international emission standards of pollutants are met by domestic industries. The Kyoto protocol to the UN convention on climate change follows the same principle in that nations are held responsible for the control of greenhouse gas emissions on their territory (UNFCCC, 1997)

The current Ecological Footprint method uses estimates of the resource consumption and waste assimilation requirements of a given population or economy in terms of its corresponding land area (Wackernagel and Rees, 1996). The 'National Footprint Accounts' (NFA) constitute the underlying methodology with which Ecological Footprints have been calculated for 149 countries of the world (published in the Living Planet Report 2004; WWF, 2004). A detailed description of the NFA method can be found in Monfreda et al. (2004) as well as a methodology paper from the Global Footprint Network (Wackernagel et al., 2004). The NFA calculate the Footprint at national level for the following categories (as an example, values in global hectares per capita for the United Kingdom in 2000 are given in brackets; data source: Moran, 2004): 1) domestic production (4.10 gha/cap), 2) imports (2.36 gha/cap), 3) stock changes (0.01 gha/cap) and 4) exports (1.16 gha/cap). The domestic production Footprint, a main component of the EF, represents the land area used by national production sectors for producing the goods and services for the final consumption of the population, including exports[2]. The Footprints of imported and exported manufactured goods is established by taking into account the embodied energies associated with their production. The accounts then estimate the apparent net consumption of a nation, deduced from 1) + 2) + 3) – 4).This results in the land area – necessary to satisfy the national demand, usually referred to as the 'national Footprint' (5.31 gha/cap).

In reply to the criticisms mentioned above it is argued therefore that the Ecological Footprint can be calculated for both consumption and production and – depending of the scope of the study – can apply different principles of responsibility. A method itself does not decide whether to measure production or consumption. Therefore, the criticism can only be aimed at specific projects like the recent Scotland study and not the method itself.

In the case of the Scotland study, the Ecological Footprint is aimed at analysing the impacts of consumption and therefore follows the "responsibility principle" where the impact of resource use is 100% attributable to a nation's residents as one way of calculating the Footprint. Important components of sustainability do lie outside of legal responsibility and can still be considered important. Most importantly, many of the indicators adopted in the UK and Scotland are related to domestic production. While there is still a lot to understand in terms of how to reduce the environmental impact of production, frameworks are in place to monitor improvements overtime. There are currently no indicators that take into account the environmental impacts in other countries that are created through the imports of goods (and the transfer of production capacity in other countries). There is the danger that the current indicators show a decoupling that takes place only within the national boundaries. Thus someone might be deluded into thinking that the trend is towards sustainability whereas in fact unsustainable production processes and emissions have merely been "exported".

It has been argued that in order to achieve equitable reduction targets, international trade has to be taken into account when assessing a nation's responsibility for abating climate change. In alternative to the principle of territorial responsibility, other approaches have been proposed in order to suggest more efficacious and fair policies, mainly distinguishing between consumer and producer responsibility. The recent paper from Bastianoni et al. (2004) provides a good review of the current state of the debate. For a very detailed and sophisticated discussion on a region's responsibility for environmental pressures we refer to Eder and Narodoslawsky (1999).

b. Data problems

McGregor et al. (2004a, p.30) argue that it is extremely difficult to trace through environmental impacts embodied in imports and that "many of the calculations in Scotland's Footprint apply average UK coefficients to Scottish data". Further, it is claimed that with the EF approach "the CO_2 embodied in the imports that enter … in Scottish consumption are not reported" (McGregor et al., 2004a, p.31).

The assessment of pollution embodiments in imported goods is a very difficult endeavour and both methods – Ecological Footprinting as well as IO analysis – have to rely on assumptions to tackle the problem. Depending, again, on the principle of responsibility that is adopted for a study, both methods employ a different approach. As demonstrated below, the NCLAS approach chosen by McGregor et al. might need a smaller amount of data but that involves far reaching assumptions, making this approach not more reliable (in terms of data) than other environmental accounting frameworks, including the Ecological Footprint.

One advantage that IO analysis has over the Ecological Footprint is that the former is able to provide a comprehensive framework to assess the direct, indirect and induced changes on the whole economy when the demand for a single product increases or decreases. We completely agree that environmental extended input-output analysis is a well established approach that allows to consequently assign resource flows and pollution generation to elements of final demand. If impacts of consumption are to be assessed holistically however, then additional data are needed, independent from the method employed. In one sense both input-output and Ecological Footprint studies require good quality data and much of this data has to be taken from national and regional surveys.

We agree with economic researchers that if we are to develop meaningful models of sustainable development then we need both a sound accounting framework and more accurate, regionally specific and timely data including trade information (compare Turner, 2003). Traditional Ecological Footprint studies – such as the recent analysis of Scotland (BFF, 2004) – rely solely on detailed data for material and energy flows as well as conversion factors expressed in physical units. We suggest that the data used in previous Ecological Footprint studies are sound even if they don't include any monetary information. In fact it could be argued that the data used in the recent Scottish input-output studies are no more accurate or precise than those used in Ecological Footprint studies. From a research perspective we need to ensure that our models of the various sectors of the economy are accurately identified and that data sets are comprehensive before exploring policy options, but this applies to both EF and IO methods. As mentioned before, we agree that economic models (based on input-output analysis) have advantages when it comes to the allocation of environmental pressures to final consumption, but this is independent from the availability of physical data.

The criticising economists modelling economic activity, waste generation, treatment and disposal in the Scottish Economy believe that if the Ecological Footprint was used then the associated data problems are too difficult to overcome. They argue that, "prohibitive data requirements would seem to rule out accurate and comprehensive Ecological Footprint measurements by input-output or any other method" (Allan et al., 2004, p.12). They continue that "we find that there are problems even within the UK in terms of data required for measuring the pollution content of inter-regional flows". And it is suggested that Ecological Footprinting "requires an enormous amount of currently unavailable data" (McGregor et al, 2004a). Obviously, there are serious data problems to be overcome in many areas of economic and environmental research but it may be asked how do input-output researchers deal with this problem?

The solution offered by McGregor et al. (2003a, 2003b, 2004a, 2004b) is termed the 'Neo-Classical Linear Attribution System (NCLAS)'. NCLAS allocates all pollution generation and resource use within a territory to the various elements of final consumption within that territory. It does so by endogenising export demand and is thought to be less data intensive than Ecological Footprint calculations. The strategy used is to assume that exports are endogenised within the system and that an "importing sector is attributed the resource use embodied in the domestic export production required to finance those imports" (McGregor, et al, 2004b, p10). Emissions generated by exports (and investment) of the domestic economy are reallocated in the input-output model and redistributed to household and government consumption. Thus environmental impacts embodied in exports are allocated pro rata to the sectors and final demand categories that import. The approach takes the view that exports essentially create the money to finance imports. In other words, the finance and pollutants generated in the production of Scottish exports are attributed to the users of imports for immediate or final demand.

Whilst this is a useful device in that it helps to close the system so that the standard Leontief matrices can be used (Leontief, 1966; Leontief, 1970), it also creates far reaching limitations in order to make the calculations feasible. In

particular, the NCLAS method is restricts its perspective to local pollution generation within the boundaries of the region or nation under investigation. McGregor et al. rightly argue that this is sensible because it is the legislature or this region or nation that has to "control the pollution generated within its own borders" (McGregor, et al, 2004b, p12). However, the NCLAS approach does not allow to draw conclusions about environmental impacts embodied in imported goods which is of increasing interest for policies on Sustainable Consumption. Certainly, the pollution that is associated with exported Scottish salmon is very different from the pollution associated with imported television sets. A holistic model needs to look at quality and quantity of both pollution at home and abroad.

The NCLAS approach is a short-cut method that absolves the researchers from obtaining specific import data. This makes the method readily available and workable, a main incentive for its creation. It should be borne in mind however, that the assumptions behind the NCLAS approach constitute a limitation of the model which Ecological Footprint analyses do not have.

Tackling the problem of environmental impacts of imports certainly requires a significant amount of research, but we would suggest that it as essential for a comprehensive assessment of consumption. This is why the Stockholm Institute are constructing a trade model that includes both the interactions between the UK and the rest of the world, as well as flows between UK regions and devolved countries.

c. The measurement problem

The third criticism of Ecological Footprinting raised in McGregor et al.'s papers is the use of standardised global hectares (gha) as units of measurement.[3] This provides a common measurement scale against which the pollutant and resource use is converted to one unit. McGregor et al. (2004a, p.30) note that "this index is a brilliant rhetorical device but is less useful for environmental management, which has to deal with individual problems".

We agree that the Ecological Footprint, measured in global hectares, is a good device for both rhetorical purposes and educational use (Moffatt, 2000). In rhetoric, the fact that we have only one Earth and that if we continue consuming resources like the USA for instance we will require several other Earth-like planets, has an impact on an audience. From a teaching perspective many people of different ages and social groups can identify with the fact that we only have one Earth and that we have to live on this planet and we must live within its biophysical limits (Ward and Dubos, 1972). It should be recognised that one of the criteria of any indicator of sustainability is that it has to be easily grasped and is capable of being communicated effectively to the public. In this sense the Ecological Footprint and its measurement unit of global hectares per capita is very effective. The Ecological Footprint has been offered as an indicator of sustainable development in the European Common Indicators study (Ambiente Italia, 2003). There can be no doubt that for many people the Ecological Footprint has a pedagogic appeal but the question for researchers is not whether the Ecological Footprinting or input-output methods are good to look at but are they useful for contributing to the process of making development sustainable.

From a methodological perspective it is important to see if measuring the Ecological Footprint in global hectares is sound. In this case some basic principles of physical science come into play. Ecological Footprint researchers acknowledge that we only have one Earth and at the same time point out that we already exceed the Earth biological capacity to deal with our resource and assimilation demands. As the latest Living Planet Report (WWF, 2004) shows this 'overshoot' was estimated to be about 20% in 2001, see Figure 1.

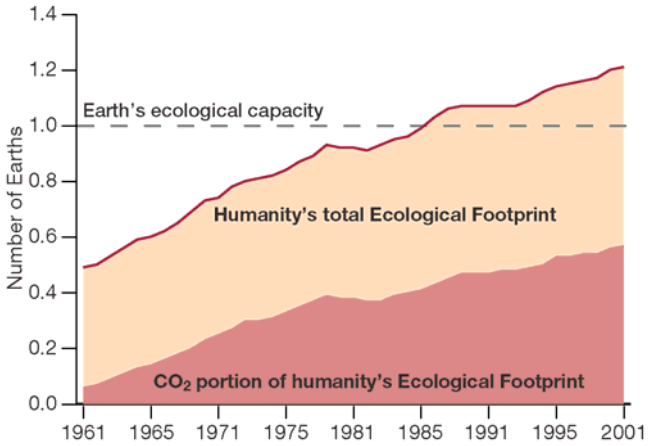

Figure 1: Ecological overshoot – humanity's Ecological Footprint (1961-2001) exceeds the ecological capacity of planet earth, (adopted from WWF, 2004)

It is clear that we cannot live beyond what is physically feasible. From the principles of the conservation of matter we cannot make matter but we can change its form. From the laws of thermodynamics we cannot get any more energy from a machine than we put into it. From ecology we cannot expect a receiving environment to exceed its assimilative capacity without increasing levels of pollution above a natural level and decline in biodiversity. Currently, economic activities such as burning fossil fuels and alteration to the land cover has increased the atmospheric CO_2 burden well in excess of natural levels (Gorshkov, 1995).

The application of scientific principles means that we have to ensure that all our mass balances add up (conservation of mass) and that we do not try to exceed the laws of thermodynamics and that polluting activities do not exceed the assimilative capacities of receiving environments. Given these scientific principles then it is clear that one way of measuring the resources available to humankind is to use the total surface of the Earth as a limiting factor. Ecological Footprinting studies acknowledge that the earth's surface has to provide our basic needs (water, food, fuel) as well as supporting all the rest of life on the planet and to sequesters

atmospheric CO_2 emissions. If this method is adopted then the global hectare is a useful measuring device for accounting for resource use and sequestration of CO_2. Of course putting these principles of science into economics has not met with much success despite the efforts of Daly's Steady State Economy (Daly, 1977) and work on entropy and economics processes (Georgescu-Roegen, 1971). Those who assume that we can live beyond these means are unaware of, or ignore, the biophysical limitations of the planet.

We acknowledge that the current Ecological Footprint method has its limitations when it comes to the distinction between sustainable and unsustainable use of land and multiple land use which are not appropriately captured within the aggregated measure of 'global hectares' (see e.g. Van den Bergh and Verbruggen, 1999). Various research efforts – mainly by Manfred Lenzen et al. from the School of Physics at the University of Sydney – are under way to specify the way land is actually used and to incorporate it in EF calculations. In Lenzen and Murray (2001) for example they apply input-output analysis to base Footprint estimates on actual – instead of hypothetical – land use and land disturbance in Australia. They also take into account greenhouse gases other than CO_2 and emission sources other than energy use and introduce a new land type category called 'emissions land'.

In a study, using input-output analysis, the researchers (Proops et al, 1999) have examined the use of non-renewable resources that accompany trade to modify the Genuine Savings index (Pearce and Atkinson, 1993). Similarly, Atkinson and Hamilton have calculated an ecological balance of payments for 95 countries; the ecological balance being defined in that study as the use of global resources minus its production of resources from domestic sources (Atkinson and Hamilton, 2002). Unsurprisingly, the OECD countries are net consumers of global resources and the Middle East and North Africa net suppliers. These two input-output studies, using the neo-classical derived Genuine Savings as a measure of sustainability, are diametrically opposed to the findings of the Living Planet Report 2004 (WWF, 2004). While the economic input-output studies, using the Genuine Savings index as a measure of sustainability, show that these nations are still sustainable, the National Footprint Accounts from the Living Planet Report show the clear opposite. The Ecological Footprinting studies – using global hectares as unit of measurement – have shown that our consumption of resources is being played out at the expense of the rest of the biotic resources of the planet and that present consumption levels in wealthy countries are unsustainable.

A way forward

There is no case of input-output analysis versus Ecological Footprinting and we do not see NCLAS as an alternative to EF as comments and titles from McGregor et al. (2004) might suggest. There are advantages and disadvantages in both approaches and they constitute two co-existing, even complementary models that answer different research and indeed political question. We can also see clear benefits in using input-output analysis with EF analyses. The Stockholm Environment Institute (SEI) have integrated Material Flow Analysis and Ecological Footprinting using tonnes and global hectares as units, respectively, into an input-output framework using monetary accounts (Wiedmann and Barrett, 2005). The method has been employed in the UK and Wales (Barrett et al., 2005) and is consistent with both standard economic accounting frameworks and the National Footprint Accounts from the Global Footprint Network. As mentioned above, a further EF study employing this method is currently being undertaken in Scotland, managed by WWF-Scotland, in partnership with North Lanarkshire Partnership and Aberdeenshire County Council. Sub-national areas are modelled by combining national IO analysis with locally specific expenditure data. Also, SEI is developing an international trade model that allows researchers to identify different levels of environmental pressures depending on where imports come from.

As sustainable development is concerned with the dynamics of change in both economic and environmental systems it would be very rewarding to model these changes over time. Again the problem of using good quality data over a long time horizon arises. Scotland does have detailed data in the form of input-output tables for such a task (Economics Advice and Statistics, 1998; Scottish Executive, 2002). This would be an important research agenda and could reveal the determinants of the changes in the environment and the economy. These environmental changes may be attributed to changes in the global economy, including policy changes, rather than just normal variations to the environment. The recent attempts to incorporate some sustainability indicators into computable general equilibrium model of the Scottish Economy (Fergusson, et al, 2004) is a welcome step. It should be noted that including dynamics into Ecological Footprinting and input-output studies ought to be encouraged (Moffatt et al, 2001) although this would add to the methodological and data problems rather than simplify them.

Researchers using Ecological Footprints and/or input-output analysis in their studies of environmental/economic interactions are aware of the need for good quality, timely data. It would be useful to have this data at a bottom up level and then environmental and economic policies could be targeted at the level of individual sectors of the economy. At present, however, Scotland has a good set of data for input-output studies and there is no reason why this data and other sources could not be mined to see the usefulness of Ecological Footprinting and input-output methods. It is recommended that Ecological Footprint and input-output researchers examine time series data for Scotland to see the advantages and limitations in the methods they use. This would be a difficult task but a potentially rewarding one for those interested in sustainable development. This would

also clarify some of the methodological difficulties inherent in either the input-output and Ecological Footprint methods and would also be useful for policy makers.

Concluding comments

This paper has re-examined the three criticisms of Ecological Footprinting raised in several papers on the impact of the Scottish economy on the local environment. We have noted that whilst legally polluters are responsible for controlling their own pollution within their own borders, it is clear that a morally responsible position has also to be adopted. In the case of Ecological Footprinting either a responsibility (consumption) or a territorial (production) principle can be applied. When the territorial principle is used then the legal and geographical boundaries of regulation coincide, when the responsibility principle is used then Ecological Footprinting researchers are concerned with more than their own backyard.

Whilst IO analysis clearly provides a comprehensive framework to enable the inclusion of all upstream impacts of industrial production, it remains just an alternative – albeit sophisticated – attribution method of environmental pressures that needs to be complemented by international trade (balance) models such as the National Footprint Accounts.

When attention is turned to the Ecological Footprinting methodology it can be seen that it is internally consistent and like input-output it uses a valid accounting framework. If a Material Flow Analysis is used then the units are in tonnes and when the Ecological Footprint is used its numeraire is global hectares rather than money.

The fundamental difference between input-output and Ecological Footprinting studies resides in the fact that neo-classical economists tend to subsume the environmental sector as a subset of the economy whilst the environmentalists tend to see the economy as a subset of the environment. This has led to an ongoing debate over whether or not sustainable development can be viewed as “weak” or “ strong” (Pearce and Barbier, 2000). Those who favour the weak approach would try to account for environmental problems as wrongly priced goods. Conversely the ecologists see strong sustainability as a pre-requisite for economic activity to continue. Putting a price on the last species or asking what people are willing to pay for the use of the last life belt on the Titanic, may be good for neo-classical theorists, but does not prevent the ship from sinking! This ideological difference, however, cannot be settled purely by adopting one approach. It is, however, vital that the methodological frameworks employed to resolve the problems of economic environmental interactions are carried out in coherent and careful manner. Nevertheless, if this work were pursued then it would cast light, rather than generate heat, on improving our understanding on how to combine polices and co-ordinate measures to better integrate economic and environmental activity in a socially just way.

It is recommended that Ecological Footprint and input-output analysts should examine sets of time series data to see the advantages and limitations in the methods they use. We contend that despite the different approaches used for Ecological Footprint and input-output investigations both contribute to this debate and practice.

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Endnotes

[1] All four papers are referred to as “McGregor et al., 2004”.
[2]Another example for production Footprint calculations is given in Ferng, 2001.
[3]One global hectare reflects the productivity of a world average bioproductive hectare.