Green National Income and the Agricultural Sector in Scotland – A Combined Accounting and Modelling Approach

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Abstract

There is a feeling that reporting the level of GDP for a country does not do justice to all aspects of economic life in relation to nature. Natural resources and ecosystem services are almost completely neglected when arriving at the number for GDP. This paper estimates for Scotland an extended GDP level that takes into account negative and positive externalities. We first show the theoretical background of extending GDP with amendments that represent, for instance, natural resource degradation. We show in a model the items that are determined using green accounting principles to adjust the level of GDP for Scotland. The resulting green national income should be interpreted with care as it does not provide information on whether or not the Scottish economy is on a sustainable path or not. Under certain circumstances green national income can be considered a measure of welfare. The accounting methodology is applied to Scotland by updating the results of the Jacobs and SAC report (2008). The final part of the paper discusses a model that can complement the accounting approach and allows analysing the consequences of policy measures on Green national income.

Keywords: Green Accounting, Sustainability, Welfare.

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1 Introduction

The Scottish Government has set certain strategic objectives in its National Performance Framework (see http://www.scotland.gov.uk/About/scotPerforms). It wants to make Scotland wealthier and fairer. The aim is to transform Scotland in a country such that “we live in a Scotland that is the most attractive place for doing business in Europe; we realise our full economic potential with more and better employment opportunities for our people”. A similar target is to make Scotland smarter, “we are better educated, more skilled and more successful, renowned for our research and innovation; we have improved the life chances for children, young people and families at risk”. Other targets are to make Scotland healthier, safer and stronger, and, finally, greener. The target greener aims at “improve Scotland's natural and built environment and the sustainable use and enjoyment of it”.

To set targets like this it is necessary to make these targets operational by devising practical targets that can be measures and followed over time to see if the policy has a positive effect and needs amending. Policy makers could focus for instance on GDP for this. After all, the level of Gross Domestic Product (GDP) for a country summarizes in one composite number the total level of output, or equivalently, total income. As income and expenditures are equal it also represents total expenditure of a country. Yet many non-market transactions are unaccounted for. Nature is an example of a good that has value, but it is not part of GDP. Especially with the last target of greener, conventional GDP is not sufficient. To deal with this issue it is possible to extend GDP to incorporate non-market items. Such an amended GDP, or Green GDP, can then assist policy makers when devising new policy measures or adjust policy measures to achieve the greener target. Instead of conventional accounting, green or environmental accounting is used to set up Green GDP.

The agricultural sector in almost any country deals with a large proportion of the land area available in that particular country. Agriculture needs water for crops to grow. As such, water and land are used and maintained by a sector that in GDP terms contributes relatively little to total GDP. A large part is nature is then under control of or influenced by the agricultural sector. Because of this special feature of the agricultural sector it is worthwhile to focus on this sector in particular when setting up a framework for environmental accounting. The Jacobs report (Jacobs and SAC, 2008) estimates for Scotland what adjustments are needed to arrive at green national income with a special focus on the agricultural sector.

This paper discusses in detail how environmental accounting and conventional accounting are related to each other. A theoretical model is developed in Section 2.1 that shows that if certain conditions are met, net national product in a broad sense can be a measure of welfare. Green Accounting and sustainability are concepts that can be linked to the theoretical model. Section 2.2 discusses some of the literature that deals with how the concept of Green GDP has to be extended to deal with issues that affect Green GDP. Examples are technological progress and price changes of exported products. In

Section 2.3 it is shown that Green GDP is inappropriate as a measure of sustainability. The theoretical model provides the basic building stones of an environmental accounting framework in Section 3.1. This framework is based on the Jacobs report and the reported numbers of the report are for the year 2007. Section 3.2 discusses in summary form the results for Scotland. In Section 3.3 a first attempt to update the results of the Jacobs report are presented. The link with the green accounting framework used is closely linked to the United Nations' System of Environmental-Economic Accounting and this is discussed in Section 4. The usefulness of the environmental accounting framework and a modelling approach is discussed in Section 5. This Section discusses how a dynamic macroeconomic model can be employed that provides the means to determine how Green GDP will develop over time. Policy measures devised can be assesses based on the positive or negative effects they have on Green GDP. At least in theory (the model is not yet fully calibrated and estimated), such a model would provide a practical tool for policy makers that can help them devise policy measures and see what the consequences are of these measures on Green GDP.

2 Green Accounting

To understand the link between conventional GDP, Green GDP, the valuation of ecosystem services and how they are related, it is very instructive to consider this in the framework of a dynamic optimal control model (Chiang, 1997). It is also useful to consider flows and stocks separately. Section 2.1 is based on Vellinga and Withagen (1996). The approach in the next section is a simplified version and Section 2.2 discusses how this simplified approach could be extended taking into account more practical situations. A related concept is sustainability and this is discussed in Section 2.3.

2.1 Theoretical Model for Green Accounting

Consider for instance the following stocks: the stock of man-made physical capital ($K(t)$), the stock of nature ($N(t)$) and the stock of pollution ($S(t)$). Households care about consumption ($C(t)$), the stock of nature and the stock pollution. It is assumed that households care less about returns further in time. This is represented by a positive discount factor ρ, the rate of time preference. Households maximize a utility function dependent on the three aforementioned items they care about, subject to constraints describing the evolution over time of the various stocks. It is assumed that the initial values of the stocks are all known. We can formulate the central planner's maximization problem as follows:

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\begin{aligned}
&\max_{I_t} \int_0^\infty e^{-\rho \cdot t} \cdot U(C(t), N(t), S(t)) \cdot dt \\
&s.t. \quad \dot{K}(t) = F(K(t), L(t)) - C(t) - J(t) - \delta^K \cdot K(t) \\
&\qquad \dot{N}(t) = E(N(t), \varphi \cdot F(K(t), L(t)) \\
&\qquad \dot{S}(t) = \varphi \cdot F(K(t), L(t)) - \mu(J(t)) \cdot S(t)
\end{aligned}
$$

The utility function is such that the marginal utility of consumption and nature are both positive, while stock pollution decreases the level of utility. Nature growth is positive dependent on the size of the stock of nature and depends negatively on the size of production (φ is larger than zero). The stock of pollution increases by the flow of pollution, which is assumed to be dependent on the level of production, and deteriorates naturally. The latter is depends positively on the level of abatement $J(t)$. To solve the maximization problem, we setup the current value Hamiltonian (Chiang, 1997):

$$\begin{aligned} H = U(C,N,S) &+ \lambda^K \cdot (F(K,L) - C - J - \delta^K \cdot K) \\ &+ \lambda^N \cdot (E(N, \varphi \cdot F(K,L))) \\ &+ \lambda^S \cdot (\varphi \cdot F(K,L) - \mu(J) \cdot S) \end{aligned} \tag{1}$$

It should be noted that the time subscripts have been left out. The first-order conditions with respect to the instruments (consumption and payments to improve the natural capital stock) are[2]:

$$H_C = U_C - \lambda^K = 0 \tag{2}$$

$$H_J = -\lambda^K - \lambda^S \cdot \mu'(J) = 0 \tag{3}$$

These first two first-order conditions concern the optimal allocation of the two instruments. The first first-order condition states that in the optimum case it does not pay to transform one unit of output from consumption to investment in capital, or vice versa. Less consumption means a lower level of utility, it decreases by U_C. More capital is worth λ^K, which is the shadow price of capital or the value attached to one extra unit of physical capital. In the optimum case, these two are equal. The second first-order condition states that an extra unit of output spend on improving the natural capital stock, which could have been used for investment, yielding a value of λ^K, is in the optimum equal to the value it delivers by

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[2] These first order conditions are for a so-called interior solution where the values of the instruments are all larger than zero. An interior solution is assumed to exist or an interior solution exists because of the specification of the utility function. For instance, the level of consumption will be larger than zero if a log-utility function is used. With a zero level of consumption the marginal utility level is infinite and this guarantees that consumers will choose a positive consumption level instead of a zero consumption level (this part of the text is based on Vellinga, 1999).

improving the way the stock of pollution dissolves by $\mu'(J)$ valued at the shadow price of stock pollution λ^S. The first-order conditions with respect to the stocks are[3]:

$$H_K = \rho \cdot \lambda^K - \dot{\lambda}^K = \lambda^K \cdot (F_K(K,L) - \delta^K) + \lambda^N \cdot E_2 \cdot \varphi \cdot F_K(K,L) + \lambda^S \cdot \varphi \cdot F_K(K,L) \quad (4)$$

$$H_N = \rho \cdot \lambda^N - \dot{\lambda}^N = U_N + \lambda^N \cdot E_1 \quad (5)$$

$$H_S = \rho \cdot \lambda^S - \dot{\lambda}^S = U_S - \lambda^S \cdot \mu(J) \quad (6)$$

These three first-order conditions are the efficiency conditions for the optimal allocation of the three stock variables. This can be interpreted as follows (Perman, Ma, and McGilvray 1996): Suppose that at the beginning of the period, you buy one unit of capital and you sell this unit at the end of this period. Consider the pay-off at the end of this period which consists of the following parts. Because of the extra unit of capital, you can produce more, namely $F_K(K,L)$ more units of output. These can be invested and their value is $F_K(K,L)$ times the value of one unit of capital, or λ^K. The extra unit of capital also depreciates in that period by δ^K and this lost unit of capital is valued at the shadow price of capital, or $\delta^K \cdot \lambda^K$. However, more capital also leads to higher production that has a negative effect of the stock of nature. This is valued at the shadow price of nature, or $\lambda^N \cdot E_2 \cdot \varphi \cdot F_K(K,L)$. More capital also leads to more flow pollution and ultimately a larger stock of pollution. This is valued at the shadow price of stock pollution, or $\lambda^S \cdot \varphi \cdot F_K(K,L)$. The value attached to an extra unit of stock pollution is the shadow price of stock pollution and is, of course, negative, because more stock pollution leads to a lower level of utility. The value attached to capital can also increase over time (or decrease for that matter) and this is captured by $\dot{\lambda}^K$. These are the gains (by the way, two of them are negative) and we now turn to the cost of acquiring this unit of capital. We spent λ^K to buy this unit of capital and we are about to receive this amount at the end of the period, so we have a capital loss, because we could have placed this money in a bank and we would have received interest in the amount of $\rho \cdot \lambda^K$. These are the opportunity costs of acquiring the unit of capital. In the optimum case, this cost is equal to the sum of the gains. The interpretation of the other two first-order conditions is comparable to the interpretation of the first-order condition for physical capital.

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[3] A time derivative is denoted by a dot over a variable.

To show the relationship between the current value Hamiltonian H and welfare, we first define the variable $W(t)$:

$$W(t) = e^{\rho \cdot t} \cdot \int_t^{\infty} \rho \cdot e^{-\rho \cdot s} \cdot U(C,N,S) \cdot ds \tag{7}$$

Thus, $W(t)$ gives total future welfare from t onwards, discounted to t. We proceed by deriving an expression for the time derivative of the current value Hamiltonian (it is assumed implicitly that everything is evaluated in the optimum):

$$\dot{H} = \frac{\partial H}{\partial K} \cdot \dot{K} + \frac{\partial H}{\partial N} \cdot \dot{N} + \frac{\partial H}{\partial S} \cdot \dot{S} + \frac{\partial H}{\partial C} \cdot \dot{C} + \frac{\partial H}{\partial J} \cdot \dot{J} + \frac{\partial H}{\partial \lambda^K} \cdot \dot{\lambda}^K + \frac{\partial H}{\partial \lambda^N} \cdot \dot{\lambda}^N + \frac{\partial H}{\partial \lambda^S} \cdot \dot{\lambda}^S + \frac{\partial H}{\partial t}$$

The problem at hand is an autonomous problem because there is no explicit time argument in the utility function and the equations describing the evolution over time of the three stock variables. We therefore must have that $\partial H / \partial t = 0$ (page 190 in Chiang, 1997). Using this result and the first-order conditions:

$$H_C = H_J = 0 \tag{8}$$

$$H_K = \rho \cdot \lambda^K - \dot{\lambda}^K \tag{9}$$

$$H_N = \rho \cdot \lambda^N - \dot{\lambda}^N \tag{10}$$

$$H_S = \rho \cdot \lambda^S - \dot{\lambda}^S \tag{11}$$

We can rewrite the above expression as:

$$\dot{H} = \rho \cdot \left(\lambda^K \cdot \dot{K} + \lambda^N \cdot \dot{N} + \lambda^S \cdot \dot{S}\right) \tag{12}$$

Remembering that the current value Hamiltonian can also be written as:

$$H = U(C,N,S) + \lambda^K \cdot \dot{K} + \lambda^N \cdot \dot{N} + \lambda^S \cdot \dot{S} \tag{13}$$

In that case, the expression for the time derivate of the present value Hamiltonian becomes:

$$\dot{H} = \rho \cdot \left(H - U(C,N,S)\right) \tag{14}$$

This is an ordinary differential equation that can be solved for H once an extra condition is introduced that makes a statement about the value of the Hamiltonian at time t going to infinity. This condition is another necessary condition, the transversality condition:

$$\lim_{t\to\infty} H \cdot e^{-\rho \cdot t} = 0 \tag{15}$$

Using this transversality condition, the differential equation can be solved uniquely and the solution reads:

$$H(t) = e^{\rho \cdot t} \cdot \int_{t}^{\infty} \rho \cdot e^{-\rho \cdot s} \cdot U(C, N, S) \cdot ds \tag{16}$$

In the optimum, the current value Hamiltonian is equal to total future welfare from t onwards, discounted to t. So the current value Hamiltonian is equal to welfare W_t as defined before. The Hamiltonian is green national income as it takes into account consumption, nature and stock pollution. As conventional national income only looks at consumption, we can now provide expressions for the adjustments to conventional GDP to arrive at green GDP. As mentioned before, green GDP (in utility terms) is equal to the current value Hamiltonian:

$$GDP^{Green} = U(C, N, S) + \lambda^{K} \cdot \dot{K} + \lambda^{N} \cdot \dot{N} + \lambda^{S} \cdot \dot{S} \tag{17}$$

Green national income includes the stock of nature and the stock of pollution. In conventional national income accounting, these items are not included. To be able to derive practical results we first linearize utility to arrive at:

$$GDP^{Green} = U_C \cdot C + U_N \cdot N + U_S \cdot S + \lambda^{K} \cdot \dot{K} + \lambda^{N} \cdot \dot{N} + \lambda^{S} \cdot \dot{S} \tag{18}$$

One of the first-order conditions gave the equality between marginal utility and the shadow price of capital, or $U_C = \lambda^{K}$ and we can rewrite the above expression to:

$$GDP^{Green} = \lambda^{K} \cdot (C + \dot{K}) + U_N \cdot N + U_S \cdot S + \lambda^{N} \cdot \dot{N} + \lambda^{S} \cdot \dot{S} \tag{19}$$

Net investment is denoted by $\dot{K}$ and it is equal to gross investment minus depreciation of the man-made capital stock, or $I^{Gross} - \delta^{K} \cdot K$ and Green GDP becomes:

$$GDP^{Green} = \lambda^{K} \cdot (C + I^{Gross} - \delta^{K} \cdot K) + U_N \cdot N + U_S \cdot S + \lambda^{N} \cdot \dot{N} + \lambda^{S} \cdot \dot{S} \tag{20}$$

Which is equivalent to:

$$GDP^{Green} = \lambda^K \cdot (C + I^{Gross}) + U_N \cdot N + U_S \cdot S + \lambda^N \cdot \dot{N} + \lambda^S \cdot \dot{S} - \lambda^K \cdot \delta^K \cdot K \qquad (21)$$

Conventional GDP in utility terms is the expression $\lambda^K \cdot (C + I^{Gross} + J)$. Here we ignore items like exports, imports, government spending and the like. The relationship between green and conventional GDP becomes:

$$GDP^{Green} = GDP^{Conventional} + U_N \cdot N + U_S \cdot S - J + \lambda^N \cdot \dot{N} + \lambda^S \cdot \dot{S} - \lambda^K \cdot \delta^K \cdot K \qquad (22)$$

Welfare or Green GDP is conventional GDP plus the value of ecosystem services ($U_N \cdot N$), disutility because of the stock of pollution ($U_S \cdot S$), minus abatement, the value of depreciation of natural capital ($\lambda^N \cdot \dot{N} + \lambda^S \cdot \dot{S}$) and minus the depreciation of man-made capital ($\lambda^K \cdot \delta^K \cdot K$).

The above given expression is for green GDP is in utility terms. It is possible to convert the two GDP measures in terms of utility into GDP measures in terms of money by using so-called real Divisia prices (for details, see Sefton and Weale, 2000). This is done by constructing the Divisia price index (π) and dividing the above given expression by this index:

$$\begin{aligned} GDP^{Green} = GDP^{Conventional} &+ (U_N / \pi) \cdot N + (U_S / \pi) \cdot S - J \\ &+ (\lambda^N / \pi) \cdot \dot{N} + (\lambda^S / \pi) \cdot \dot{S} - (\lambda^K / \pi) \cdot \delta^K \cdot K \end{aligned} \qquad (23)$$

In general, the co-state variables or shadow prices (like λ^N) represent the present discounted value of marginal contributions (see Equation 44 in Blanchard and Fisher (1989) on page 62):

$$\lambda^N(t) = e^{\rho \cdot t} \cdot \int_t^\infty e^{-\rho \cdot s} \cdot \frac{\partial H}{\partial N} \cdot ds \qquad (24)$$

Based on this observation, it is also possible to say more about the price used for determining the value of ecosystem services of nature. The expression used is one of the first-order condition and in particular the one for nature:

$$H_N = \rho \cdot \lambda^N - \dot{\lambda}^N = U_N + \lambda^N \cdot E_1 \qquad (25)$$

This can be rewritten as:

$$\dot{\lambda}^N = \rho \cdot \lambda^N - U_N - \lambda^N \cdot E_1 \qquad (26)$$

Or, in this case:

$$\lambda^N(t) = \int_t^{\infty} e^{-(\rho - E_1)\cdot(s-t)} \cdot U_N(C(s), N(s), S(s)) \cdot ds \tag{27}$$

The shadow price of nature is the present value of marginal utility values with respect to nature. This shadow price is not observable and that is where the great difficulty lies. The society as a whole has to decide on the right aggregate social function dependent on consumption, nature and stock pollution. It can be expected that it is difficult to get a census opinion on this.

2.2 Green Accounting and Non-Autonomous Items

The results in Section 2 are valid when there is no time components in, for instance, the production function $F(K,L)$. If such a time component is present, the motion of the state variables become non-autonomous. Such cases extend the analysis of Section 2. And this can be done in many different ways. The first would be technical progress and this has been dealt with by Aronsson and Löfgren (1993) in the case of the classical Ramsey model without trade, no exhaustible resources and no pollution. They state that with anticipated technical progress, the current value Hamiltonian underestimates welfare. Varying world market prices of raw materials are analysed further by Sefton and Weale (1996).

2.3 Green Accounting and Sustainability

We follow Vellinga and Withagen (1996), by defining sustainable development as a situation where the value of the instantaneous utility function $(U(C,N,S))$ is constant. In that case it is easy to calculate what the level of welfare $W(t)$ will be, given by Equation 7. Welfare will be equal to this constant level of utility. As the Hamiltonian equals welfare, we must also have that the Hamiltonian is constant over time, compare Equation 16 and 7. A necessary condition for sustainability is thus that the value of investment is constant over time (see also Withagen, 1996). Investment is understood to be broadly defined. Not only encompassing it man-made physical stock, but also stocks of nature for example. This corresponds to Hartwick's rule which states that if investment in all man-made and natural capital is zero for all time periods, we have constant consumption. This must be true for all time periods. Observing over a period of time a zero net investment does not mean that the economy is on a sustainable path (see Asheim et al. 2003, on page 139). Similarly, even if net investment is negative can an economy still be on a sustainable path (see Asheim et al. 2003, on page 142). Asheim et al. go on and argue that Hartwick's rule seems more natural to be considered as a descriptive result.

3 Measuring Green GDP in Scotland

The framework for green accounting with the link to the theoretical model of the previous sector will be discussed in Section 3.1. Section 3.2 deals with the practical application of this approach and discusses the results for Scotland. And Section 3.3 discusses preliminary results of updating the Jacobs report.

3.1 Green Accounting Framework

As shown in the previous section, green national income is encompassing more than conventional national income as it incorporates various stocks of natural capital and stocks of pollutions. Let us denote the individual adjustment items as follows (both levels of GDP are in money terms):

$$GDP^{Green} = GDP^{Conventional} + B + E - J - \delta K_N - \delta K_M \tag{28}$$

Where:

- B is the flow of non-market environmental benefits
- E is the costs or dis-amenity arising from non-market environmental emissions
- J is the government expenditure on the environment (e.g. through agri-environment payments)

This is in accordance with text in Box 1 on page 7 of the Jacobs report (Jacobs and SAC, 2008). To relate to the variable names in the Jacobs report, there are the following relationships with the equation for the theoretical model of the previous Section and the items in Box 1:

$$B = (U_N / \pi) \cdot N \tag{29}$$

$$E = (U_S / \pi) \cdot S \tag{30}$$

$$\delta K_N = -(\lambda^N / \pi) \cdot \dot{N} - (\lambda^S / \pi) \cdot \dot{S} = (\lambda^N / \pi) \cdot (-\dot{N}) + (\lambda^S / \pi) \cdot (-\dot{S}) \tag{31}$$

$$\delta K_M = (\lambda^K / \pi) \cdot \delta^K \cdot K \tag{32}$$

Each of the items B and E are measured by a physical quantity and a value per unit of this physical quantity. Following the Jacobs report, the items included in the flow of non-market environmental benefits (B) are farmland birds, natural structures that have a length and are measured in number of kilometres, and natural structures that have an area and are measured in hectares. The following tables give the items of the latter two:

Table 1: Natural structures that have a length.

Name	Unit
Hedge	km
Remnant hedge	km
Line of trees/shrub/relict hedge and fence	km
Line of trees/shrub/relict hedge	km
Total Field Margins	km
Bank Grass Strip	km

Table 2: Natural structures that have an area.

Name	Unit
Improved Grassland	ha
Arable and Horticultural	ha
Neutral Grassland	ha
Bog	ha
Dwarf Shrub Heath	ha
Acid Grassland	ha
Fen, Marsh and Swamp	ha
Calcareous Grassland	ha
Farm Woodland	ha
Arable and Horticultural	ha
Arable and Horticultural	ha
Neutral Grassland	ha
Neutral Grassland	ha
Bog	ha
Dwarf Shrub Heath	ha
Acid Grassland	ha
Fen, Marsh and Swamp	ha
Calcareous Grassland	ha

For the farmland bird population there is no data in the Jacobson report. As an example of natural structures that have a length, remnant hedges have in total a length of 530 kilometres. These remnant hedges are valued at 43 GBP per kilometre. In total, the 530 kilometres of remnant hedges are valued at 12,190 GBP.

The items so far do not have a market valuation. The underlying stock provides ecosystem services which have a certain value as these ecosystem services are part of the social utility function. The valuation provides an estimate for the shadow price and measures the present value of marginal utility values with respect to nature for example. See Equation 27 in the previous section.

Among the items included in E are the items listed in the following table:

Table 3: Environmental emissions items and their unit of measurement.

Item	Unit
Length of rivers and canals of 'fair' quality (chemical quality indicator)	km
Length of rivers and canals of 'poor/bad' quality (chemical quality indicator)	km
Apportionment of total damage cost due to eutrophication in lakes	
Number of coastal bathing waters failing to meet EU standards for faecal contamination at least 80% of the time	
Length/area of estuarine waters of 'fair' quality (combined chemical, biological and aesthetic indicators)	km/km^2
Length/area of estuarine waters of 'poor' or 'bad' quality (combined chemical, biological and aesthetic indicators)	km/km^2
Agricultural abstraction	Ml/day
Total general agricultural waste	tonne

The remaining items are given in the following table. They entail the government expenditure on the environment to improve the environment. In theory they are also part of the valuation of the depreciation of natural capital, but as such there are no items for this in the Jacobs report:

Government expenditure on the environment and the depreciation of natural capital items.
Nitrates in drinking water
Pesticides in drinking water
Cryptosporidium in drinking water
Sediment in drinking water
Number of category 1 or high severity pollution incidents from agriculture
Number of category 2 or medium severity pollution incidents from agriculture
Flooding attributed to agriculture
Off-site damage from soil erosion (% attributable to agriculture)

3.2 Green National Income for UK and Scotland in 2007

The following table shows the results of the Jacobs report for Green national income for Scotland for the year 2007. The totals for UK are also listed in the table for comparison. Whenever an item is not available for Scotland it is marked with NA.

Table 4: From conventional national income to Green national income for Scotland and UK.

Conventional GNI		Physical data	Value in £	Value in £m	UK
+B	Improved Grassland (non SSSI) (hectares)	1,051,000	Not valued	NA	
	Arable and Horticultural (non SSSI) (hectares)	639,000	Not valued	NA	
	Neutral Grassland (non SSSI) (hectares)	168,000	90	15	
	Bog (non SSSI) (hectares)	2,038,000	99	202	
	Dwarf Shrub Heath (non SSSI) (hectares)	1,002,000	25	25	
	Acid Grassland (non SSSI) (hectares)	748,000	90	67	
	Fen, Marsh and Swamp (non SSSI) (hectares)	337,000	99	33	
	Calcareous Grassland (non SSSI) (hectares)	27,000	90	2	
	Farm Woodland (hectares)	249,290	145	36	
	Total			381	593
	Arable and Horticultural (SSSI favourable condition) (hectares)	NA	NA	NA	
	Arable and Horticultural (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Neutral Grassland (SSSI favourable condition) (hectares)	NA	NA	NA	
	Neutral Grassland (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Bog (SSSI favourable condition) (hectares)	NA	NA	NA	
	Bog (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Dwarf Shrub Heath (SSSI favourable condition) (hectares)	NA	NA	NA	
	Dwarf Shrub Heath (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Acid Grassland (SSSI favourable condition) (hectares)	NA	NA	NA	
	Acid Grassland (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Fen, Marsh and Swamp (SSSI favourable condition) (hectares)	NA	NA	NA	
	Fen, Marsh and Swamp (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Calcareous Grassland (SSSI favourable condition) (hectares)	NA	NA	NA	
	Calcareous Grassland (SSSI unfavourable condition) (hectares)	NA	NA	NA	
	Total			0	260
	Farmland bird population index	NA	NA	NA	307
	Sewage sludge disposed of on farmland (tonnes)	39,000	34	1.33	35
	Hedge (km)	1,900	23	0.04	
	Remnant hedge (km)	530	23	0.01	
	Line of trees/shrub/relict hedge and fence (km)	1,110	23	0.03	
	Line of trees/shrub/relict hedge (km)	1,330	23	0.03	
	Total Field Margins (km)	4,870	23	0.11	
	Bank Grass Strip (km)	1,240	23	0.03	
	Total			0.14	2.44
-E	Length of rivers and canals of 'fair' quality (chemical quality indicator) (km)	2,425		8.86	
	Length of rivers and canals of 'poor/bad' quality (chemical quality indicator) (km)	734		2.68	
	Total			12	62
	Eutrophication in lakes due to agricultural diffuse pollution	NA	NA	NA	27
	Number of coastal bathing waters failing to meet EU standards for faecal contamination at least 80% of the time	27		2.24	11
	Length/area of estuarine waters of 'fair' quality (combined chemical, biological and aesthetic indicators) (km/km2)	95		0.35	

	Length/area of estuarine waters of 'poor' or 'bad' quality (combined chemical, biological and aesthetic indicators) (km/km2)	22		0.08	
	Total			0.43	3
	Agricultural abstraction (megalitres per day)	155		16.41	62
	Total general agricultural waste (tonnes)	NA	NA	NA	8
-J	Nitrates in drinking water	NA	NA	NA	
	Pesticides in drinking water	NA	NA	NA	
	Cryptosporidium in drinking water	NA	NA	NA	
	Sediment in drinking water	NA	NA	NA	
	Total			0	129
	Number of category 1 or high severity pollution incidents from agriculture	NA	NA	NA	
	Number of category 2 or medium severity pollution incidents from agriculture	24		0.05	
	Total			0.05	0.53
	Flooding attributed to agriculture	NA	NA	NA	233.80
	Off-site damage from soil erosion (% attributable to agriculture)	NA	NA	NA	9.41
= Green GNI				352	654

At the top on the left we start with conventional national income. Then the items B, E and J are listed in the table together with their constituent parts below each of them. By applying the equation at the beginning of Section 3.2 you end up with Green national income at the bottom of the table. The value of the item $B+E-J$ is listed in the column at the far right at the bottom of the table. Ignoring the data that is not available, conventional GDP has to be corrected by 352 £m to arrive at Green GDP for Scotland. For the UK as a whole the correction made need to be 652 £m. This means that the agricultural sector provides a positive contribution to GDP if one takes into account unpriced natural stocks and flows.

3.3 Updating the Jacobs Report

The results in the Jacobs report are valid for 2007, although they use sometimes data from earlier years for their reporting. An important part of this project is the updating of the results in the Jacobs report. A chunk of the output of the Jacobs report is an excel sheet with the underlying calculations of the report. See http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/envacc/jacob.htm for this. The Excel sheet and the report contain the sources used for determining, for instance, the length of bank grass strips and the corresponding value.

At the moment roughly 25% of the Jacobs report has been updated. In 2014 we will work further on the updating. One finding of the updating is that the physical measurements for the items B in the report are only 10% of what we found in the material referenced in the Jacobs report. As such it seems that the results of the Jacobs report can not only be updated, but also improved whereby errors are corrected.

There is also room for possible improvement as to what items need to be included in each of the categories B, E, J, δK_N and δK_M. These are the broad impact categories. To determine what additional impact categories should be considered, we will need to consult with biologists, bio-physicists, environmentalists, and the like. At JHI there is enough expertise we expect to give us clues on what should be included and what could possibly be deleted if it is not very relevant. This means that the items may be deleted from the list already used and the list could be extended.

Finally, there are many missing items. Sometimes physical data is missing, or there is no value given for the valuation. This becomes clear from the table in the previous section. This means that there is room for improving the estimate made by Jacobs to measure green GDP in Scotland by retrieving the required figures. Existing data gaps are identified, for example, with respect to the farmland bird population. There is also missing data for most of the items in Table 2. The following table gives an overview of these items:

Table 5: Missing data items form the Jacobs report.

+B	Arable and Horticultural (SSSI favourable condition) (hectares)
	Arable and Horticultural (SSSI unfavourable condition) (hectares)
	Neutral Grassland (SSSI favourable condition) (hectares)
	Neutral Grassland (SSSI unfavourable condition) (hectares)
	Bog (SSSI favourable condition) (hectares)
	Bog (SSSI unfavourable condition) (hectares)
	Dwarf Shrub Heath (SSSI favourable condition) (hectares)
	Dwarf Shrub Heath (SSSI unfavourable condition) (hectares)
	Acid Grassland (SSSI favourable condition) (hectares)
	Acid Grassland (SSSI unfavourable condition) (hectares)
	Fen, Marsh and Swamp (SSSI favourable condition) (hectares)
	Fen, Marsh and Swamp (SSSI unfavourable condition) (hectares)
	Calcareous Grassland (SSSI favourable condition) (hectares)
	Calcareous Grassland (SSSI unfavourable condition) (hectares)
	Farmland bird population index
-E	Eutrophication in lakes due to agricultural diffuse pollution
	Total general agricultural waste (tonnes)
-J	Nitrates in drinking water
	Pesticides in drinking water
	Cryptosporidium in drinking water
	Sediment in drinking water
	Number of category 1 or high severity pollution incidents from agriculture
	Flooding attributed to agriculture
	Off-site damage from soil erosion (% attributable to agriculture)

In the remainder of the project we will try to retrieve as much of these unknown items as possible. Of course, still, it remains to be seen if in addition to the items in the previous table there are additional items need to be collected after consulting environmental experts.

An overview of the updated Green GDP figures is shown in the next table:

Impact	Scotland Env. Data	Value of flow from agriculture (£m)	Scotland old figures check Env. Data	Scotland latest figures Env. Data
Farmland bird population index	N.a	…		
Hedge	1,900	0.04	19,000.00	21,180.00
Remnant hedge	530	0.01	5,300.00	Not provided
Line of trees/shrub/relict hedge and fence	1,110	0.03	11,100.00	12,090.00
Line of trees/shrub/relict hedge	1,330	0.03	13,300.00	13,090.00
Total Field Margins	0	0.11		
Bank Grass Strip	1,240	0.03	12,400.00	6,150.00
Improved Grassland (non SSSI)	1,051,000	-	1,051,000.00	907,010.00
Arable and Horticultural (non SSSI)	639,000	-	639,000.00	534,110.00
Neutral Grassland (non SSSI)	168,000	15.12	168,000.00	461,050.00
Bog (non SSSI)	2,038,000	201.76	2,038,000.00	2,043,810.00
Dwarf Shrub Heath (non SSSI)	1,002,000	25.05	1,002,000.00	894,310.00
Acid Grassland (non SSSI)	748,000	67.32	748,000.00	982,700.00
Fen, Marsh and Swamp (non SSSI)	337,000	33.36	337,000.00	238,460.00
Calcareous Grassland (non SSSI)	27,000	2.43	27,000.00	26,120.00
Farm Woodland	249,290	36	249,290	466,759

In this table “Env. Data” refers to Environmental data and in the above table refers to number of kilometres for the items Hedge until Bank Grass strip, and hectares for the items below Bank grass Strip. We found the numbers in the 2007 Jacobs report to be 10% of what the source provides. The 2007 Jacobs report results are in column 2 and 3. The column 4 contains the check on the environmental data values by consulting the original references (Year 1998 in the Countryside Survey 2000 report). It is clear that the numbers in column 2 and 4 are not equal to each other. The numbers in column 4 are 10 times the value in column 2. The updated figures in column 5 are based on Countryside Survey 2007. This reference also contains updated data on the 1998 data used in the Jacobs report.

4 System of Environmental Economic Accounting

The United Nations (2012) have published a background document dealing with a System of Environmental - Economic Accounting (SEEA). Its purpose is to "… describe both the measurement of ecosystems in physical terms, and the valuation of ecosystems in so far as it is consistent with market valuation principles …". It is stated that only those assets that have an economic value following the valuation principles of the System of National Accounts are included in the SEEA Central Framework. In SEEA's asset accounts the focus is on the environmental assets which are listed in the following table:

Table 6: Environmental Assets dealt with in the SEEA.

Environmental Assets
mineral
energy resources
land
soil resources
timber resources
aquatic resources
other biological resources
water resources

With regard to the environmental assets considered, the SEEA is broader that the approach described in Section 2. Of course, the reason why the focus in Section 2 is not so wide is that it merely focusses on the agricultural sector.

SEEA reports physical measurements and items in monetary units. The physically measured assets includes "… all natural resources and areas of land of an economic territory that may provide resources and space for use in economic activity". Physical measurements are not limited to those assets that have economic value. The valuation of environmental assets is carried out using the net present value (NPV) approach. Important in this approach is the choice of discount rate. For environmental assets without economic value this corresponds to the B in Section 3.

Depletion in physical terms in SEEA is defined as "decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units occurring at a level greater than that of regeneration". The value of depletion can then subsequently be determined and this then corresponds to the δK_N in Section 3.

5 Green Accounting and Agriculture – Hrubovcak's Model

Determining Green GDP and follow its development over time gives an indication on how well a country like Scotland is becoming greener or not. This way it is only possible to signal a deterioration of Green GDP. It is not possible, or it is not very clear, what is causing this. To this end it pays off to additionally set up an economic-environmental model that explicitly models the interaction between economic activities and the effects of them on the environment.

A full dynamic macroeconomic model is developed by Hrubovcak et al. (2000) with the aim of looking at the agricultural sector and determining Green National Income. This approach is promising as it allows studying certain government policies and the effect of them on Green National Income. One could think of CAP reforms to determine how the level of Green National Income would change by introducing certain decoupling schemes. Would changing subsidising to farmers in a particular way lead to a deterioration of Green national income? If that would be the case, can a rearrangement of the existing subsidies be undertaken that leads to an improvement of Green national income? These and other questions can possibly be answered by employing such a model. Using this approach would enhance the usefulness tremendously of the green accounting framework as discussed in this paper. Unfortunately, the authors do not specify functional forms or calibrate the functional forms of their production functions to arrive at an operational model that can be used to assess how Green GDP will develop. The equations should represent the physical interaction of various stocks and flows in a realistic manner. If these problems have been solved or dealt with in a satisfactory manner, the reward will be a modelling framework that will complement the green accounting framework and allow studying Green National Income with various policy proposals by the Scottish Government for example.

The model of Hrubovcak et al. has the following features[4]. The consumers maximize a utility function dependent on agricultural output, non-agricultural output and the stock of clean water. The latter is an unpriced natural stock that provides ecosystem services. The utility function is maximized subject to a number of constraints. The constraints describe the evolution over time of the four stocks in the model. There is the stock of clean water, the stock of quality-adjusted agricultural land, the stock of ground water and, finally, the stock of man-made capital. Production in the agricultural sector is dependent on labour, capital, an environmental input that is being used that goes at the expense of the stock of clean water, the stock of quality-adjusted agricultural land, the amount of ground water extracted, and the stock of ground water. Output of the non-agricultural sector is dependent on labour, capital, the stock of clean water and land.

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[4] The model can be cast in a similar framework as in Section 2.1.

The four stocks in the model have equations describing the evolution over time of each of these stocks. Labour, capital and intermediate inputs are used to increase each of the stocks or extract some of it. There is also natural regeneration of a stock, like for the stock of clean water and the stock of ground water. Land is susceptible to erosion. Using clean water in production leads to a decrease of the stock of clean water. Investment takes place in man-made physical capital and due to wear and tear this form of capital depreciates over time.

There are various goods market equilibriums, like land is used in the agricultural sector and the non-agricultural sector. Similar equations are valid for labour and output of the two sectors and these equations are essentially accounting equations stating that the total supply is equal to the various demanded quantities.

In the model there are three natural capital stocks: clean water, groundwater and quality adjusted agricultural land. Clean water provides, as mentioned, ecosystem services. An equation linking conventional and Green national income can be derived in much the same way as in Section 2.1. This equation states that: Green national income is equal to conventional national income minus man-made capital depreciation, plus the value of ecosystem services of the clean water stock, minus the depreciation of the natural capital stocks, i.e. clean water, ground water and land.

The approach of Hrubovcak et al. is promising because it links the items in the green accounting framework with a model describing the functioning of an economy. The model supplements the accounting framework as it can help policy makers devising new policy measures to see the consequences of these measures on conventional income and Green national income.

6 Concluding Remarks

In this paper we discussed the theoretical background of the ideas that underlies the concepts of green national income accounting. National income can be seen as a measure of welfare if capital is defined as broad capital encompassing also natural capital stocks. Conventional income should be corrected by the value of ecosystem services of unpriced natural stocks. It should also account for the disutility of pollution and the value of the deterioration of natural capital stocks. The formula for green national income should be amended if technological progress is taken into account or when world prices are changing. It was discussed that Green national income is not a good measure of sustainability. The Hartwick rule says that only if net investment in all stocks of man-made and natural capital for all time periods is zero are we on a sustainable path. Green national income with a special focus on the agricultural sector is measured in the Jacobs and SAC report (2008). In this paper the link with their green accounting framework and the theoretical model of this paper is discussed. We also discuss how Green national income in practical terms is being measured. Preliminary results of updating these results are discussed after 25% of this work has been completed. Many missing data have been identified and left for future research. The United Nations' System of Environmental-Economic Accounting is very similar to the approach discussed in this paper. The similarities between these two approaches are discussed and it is shown that the present value method of the United Nations' approach corresponds to the value of ecosystem services of the approach in this paper. In the final section a theoretical model is presented that complements the green accounting approach and allows for an analysis of policy measures and their effect on Green national income.

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