Anomalies in Green National Accounting[*]

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Abstract

We "extend" standard arguments for greening the product side of the national accounts to the income side of the accounts and turn up an anomaly. For an economy with oil use, no entry for oil income, a supposed primary factor, appears in the income side of the national accounts when the depletion of natural capital is accounted for on the product side of the accounts. We resolve this issue by applying an income definition developed in the theory of national accounting. This, however, leads to another anomaly on the income side of the national accounts.

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1 Introduction

Central to green national accounting is the netting out from investment in new durable capital goods terms for the current draw-down in items of natural capital. Greening the national accounts involves added disinvestment terms for natural capital draw-down to traditional net national product (NNP).[1] The current value of oil stock depletion for example becomes a new disinvestment along side familiar investment in durable capital in NNP. Here we note that this netting out for natural capital draw-down on the product side of the national accounts, in NNP, has anomalous implications for the income side of the national accounts. For the case of oil, when we green NNP, we end up with an entry of zero for the value of oil as an input on the income side of the national accounts. For a natural resource with some renewal power such as a fish stock, we observe the same outcome: Greening the NNP in an appropriate way leads to an entry of zero for the value of the current quantity of fish being used, net of renewal of the stock, on the national income side of the national accounts.

We contrast these findings with the definition of income arising from the theory of national accounting as originating with Weitzman (1976) and developed further by, e.g., Sefton and Weale (2006). Based on these developments and the specific definition of sectoral income proposed by Asheim and Wei (2009) we resolve the above anomaly by showing that income to owners of natural capital is positive even if it consists solely of a non-renewable resource like oil. Instead another anomaly arises, namely that income to owners of reproducible capital becomes smaller than the value of its marginal product.

We start out by introducing a general model which allows us to establish principles for how to perform the accounting, in particular to distribute inputs like labor and different kinds of capital stocks among outputs like consumption and net changes in the capital stocks. This framework is then applied to a simple abstract economy with three goods produced — consumption, investment in reproducible capital and extraction of oil (or fish, or, later, a durable, non-renewable resource like copper). We make use of social accounting matrices since these "aids" allow us to maintain attention to the national income side of the national accounts as we lay out the

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[1]Early empirically motivated thinking about disinvestment of natural capital in the national accounts include Ward (1985), El Serafy (1989), Repetto, Magrath, Wells, Beer and Rossini (1989), Pearce and Atkinson (1993) and Hamilton and Atkinson (2006). More theoretical contributions include Weitzman (1976, 1999), Hartwick (1990), Sefton and Weale (2006) and Dasgupta (2009).

product side (the NNP). After setting out the green national accounts for an economy with oil, we consider the related non-green version of the accounts. We then turn to the cases of renewable resources and durable, non-renewable resources. We finally address the question of how the income definition arising from the theory of national accounting can be used to resolve the anomaly that no entry for natural capital appears on the income side of the accounts.

2   Social accounting matrix

The *social accounting matrix* (SAM) measures outputs (in terms of consumption and net changes in stocks) along the vertical axis and inputs along the horizonal axis. We first present a general model which allows us to establish principles for how to construct the SAM. We allow for joint production and do not explicitly consider any kind of intermediate products.

Assume that consumption C is one-dimensional while capital $\mathbf{K}$ is an n-dimensional vector which includes labor as well as different forms of reproducible and natural capital. So $\mathbf{K}$ is the input vector while $(C, \dot{\mathbf{K}})$ is the output vector, where the component of $\mathbf{K}$ corresponding to labor is assumed to constant. A output-input pair $(C, \dot{\mathbf{K}}, \mathbf{K})$ is feasible if and only if $(C, \dot{\mathbf{K}}, \mathbf{K}) \in \mathcal{Y}$ where $\mathcal{Y}$ is a convex feasible set. Assume constant returns to scale so that if $(C, \dot{\mathbf{K}}, \mathbf{K}) \in \mathcal{Y}$, then $(\lambda C, \lambda \dot{\mathbf{K}}, \lambda \mathbf{K}) \in \mathcal{Y}$, for any non-negative λ. In mathematical terms this means that $\mathcal{Y}$ is a convex cone.

Assume also that the economy is in an intertemporal competitive equilibrium. This entails (see Dixit, Hammond and Hoel, 1980) that, at all times, intertemporal profits $pC + \mathbf{q}\dot{\mathbf{K}} + \dot{\mathbf{q}}\mathbf{K}$ are maximized, where p is a present value price of consumption and $\mathbf{q}$ is a present value price vector of capital. To see that $pC + \mathbf{q}\dot{\mathbf{K}} + \dot{\mathbf{q}}\mathbf{K}$ can be interpreted as intertemporal profits, note that $pC + \mathbf{q}\dot{\mathbf{K}}$ is the value of outputs and $-\dot{\mathbf{q}}$ is the vector of rental costs of capital, all measured in present value prices.

The assumption of constant returns to scale implies that intertemporal profits are zero in a competitive equilibrium where intertemporal profits are maximized:

$$pC + \mathbf{q}\dot{\mathbf{K}} + \dot{\mathbf{q}}\mathbf{K} = 0 \,.$$

By defining current capital prices in terms of consumption, $\mathbf{Q} = \mathbf{q}/p$, we obtain:

$$C + \mathbf{Q}\dot{\mathbf{K}} = \left(r\mathbf{Q} - \dot{\mathbf{Q}} \right) \mathbf{K} \,, \tag{1}$$

where $r = -\dot{p}/p$ is the real interest rate. In this equation, $r\mathbf{Q} - \dot{\mathbf{Q}}$ is the vector of "own rates of interest" of the different forms of capital, which by invoking the

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Table 1: Example of a social accounting matrix

	input N	input K_1	input K_2	NNP
output C	wN^C	$(rQ_1 - \dot{Q}_1)K_1^C$	$(rQ_2 - \dot{Q}_2)K_2^C$	C
output $\dot{K}_1$	wN^1	$(rQ_1 - \dot{Q}_1)K_1^1$	$(rQ_2 - \dot{Q}_2)K_2^1$	$Q_1\dot{K}_1$
output $\dot{K}_2$	wN^2	$(rQ_1 - \dot{Q}_1)K_1^2$	$(rQ_2 - \dot{Q}_2)K_2^2$	$Q_2\dot{K}_2$
NNI	wN	$(rQ_1 - \dot{Q}_1)K_1$	$(rQ_2 - \dot{Q}_2)K_2$	$C + Q_1\dot{K}_1 + Q_2\dot{K}_2$

no-arbitrage equation measure both the different stocks' rental costs and the value of their productive contributions.

Now we can distribute the inputs, $\mathbf{K} = (K_0, \ldots, K_{n-1})$, among the various outputs, $C, \dot{K}_0, \ldots, \dot{K}_{n-1}$, in proportion to the values of consumption and the different components of net investment:

$$\mathbf{K}^C = \frac{C}{C + \mathbf{Q}\dot{\mathbf{K}}}\mathbf{K} \tag{2}$$

$$\mathbf{K}^i = \frac{Q_i\dot{K}_i}{C + \mathbf{Q}\dot{\mathbf{K}}}\mathbf{K} \quad \text{for each capital component } i = 0, \ldots, n-1. \tag{3}$$

To illustrate, consider the case where there are three capital goods, 0, 1, and 2, where $K_0 = N$ corresponds to the constant supply of labor. Then $\dot{K}_0 = \dot{N} = 0$ and wage w equals $rQ_0 - \dot{Q}_0$ since price Q_0 equals the present value of future wages. Write $K_0^C = N^C$ and $K_0^i = N^i$ for $i = 1, 2$. We obtain the SAM shown in Table 1. Column sums follow directly from (2) and (3), while the row sums follows when in addition (1) is applied.

The right hand column is the green net national product (NNP), which is the sum of consumption and the value of net changes in all stocks, also those corresponding to natural and environmental resources. The bottom row is the net national income (NNI) specifying how labor and the different stocks contribute to aggregate income.

3   A non-renewable resource

In the case of the Dasgupta-Heal-Solow-Stiglitz (DHSS) model (Dasgupta and Heal, 1974; Solow, 1974; Stiglitz, 1974) of capital accumulation and resource depletion, the feasibility set, $\mathcal{Y}$, is determined by $(C, -\dot{K}_2, K_1, K_2) \geq 0$, $N > 0$ constant and

$$Y = C + \dot{K}_1 \leq F(N, K_1, -\dot{K}_2), \tag{4}$$

Table 2: The social accounting matrix in the case of the DHSS model

	input N	input K_1	input K_2	NNP
output C	wN^C	rK_1^C	0	C
output $\dot{K}_1$	wN^1	rK_1^1	0	$\dot{K}_1$
output $\dot{K}_2$	wN^2	rK_1^2	0	$Q_2\dot{K}_2$
NNI	wN	rK_1	0	$C + \dot{K}_1 + Q_2\dot{K}_2$

where F is a quasi-concave and constant-returns-to-scale production function.[2] Then

(i) price Q_1 is constant and equal to 1, so that $rQ_1 - \dot{Q}_1 = r$, since production is split into consumption and net investment in reproducible capital, and

(ii) price Q_2 increases with the rate of interest by Hotelling's rule, so that $rQ_2 - \dot{Q}_2 = 0$, since K_2 is a non-renewable and exhaustible resource like oil which does not contribute productively as a stock and thus has zero rental cost.

In this case the SAM becomes the one shown in Table 2. The fact that all the entries in third column are zero is the anomaly. Oil would, one presumes, be classified as a primary factor like labor, reproducible capital, and land *a priori*. Yet when a green national account is set out, oil does not contribute to aggregate income (net national income, NNI). This is the basic anomaly.

Even if one considers a slightly more general version of this model, where consumption, investment in reproducible capital, and extraction of the non-renewable resource are separate constant-returns-to-scale functions F_C, F_I, and F_R of labor, reproducible capital, and extracted resource, the same anomaly arises. In this case, $\mathcal{Y}$ is determined by $0 \le C \le F_C(N_C, K_{1C}, R_C)$, $\dot{K}_1 \le F_I(N_I, K_{1I}, R_I)$, $0 \le -\dot{K}_2 \le F_R(N_R, K_{1R}, R_R)$, $N_C + N_I + N_R = N$, $K_{1C} + K_{1I} + K_{1R} = K_1$, and $R_C + R_I + R_R = -\dot{K}_2$, with all inputs to the functions F_C, F_I and F_R constrained to be non-negative. Still, in the end, the only difference from Table 2 is that $Q_1 \equiv 1$ and $rQ_1 - \dot{Q}_1 = r$ need not hold. The non-renewable and exhaustible resource, oil, does not appear to contribute to aggregate income in this more general model either, even though in this case extraction costs are allowed to be positive.

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[2]This formulation allows for positive depreciation of reproducible capital by letting $F(N, K_1, -\dot{K}_2) = G(N, K_1, -\dot{K}_2) - \delta K_1$, where G is a gross of depreciation production function and δ is a positive depreciation rate.

Table 3: The social accounting matrix with a Cobb-Douglas DHSS model

	input N	input K_1	input K_2	NNP
output C	$\frac{1-\alpha-\beta}{1-\beta}C$	$\frac{\alpha}{1-\beta}C$	0	C
output $\dot{K}_1$	$\frac{1-\alpha-\beta}{1-\beta}\dot{K}_1$	$\frac{\alpha}{1-\beta}\dot{K}_1$	0	$\dot{K}_1$
output $\dot{K}_2$	$\frac{1-\alpha-\beta}{1-\beta}Q_2\dot{K}_2$	$\frac{\alpha}{1-\beta}Q_2\dot{K}_2$	0	$Q_2\dot{K}_2$
NNI	$(1-\alpha-\beta)Y$	αY	0	$(1-\beta)Y$

It is instructive to look at a special case of the DHSS model. If

$$Y = F(N, K_1, -\dot{K}_2) = N^{1-\alpha-\beta}K_1^\alpha(-\dot{K}_2)^\beta\,,$$

and the economy adheres to a classical utilitarian criterion with $U(C) = C^{1-\eta}/(1-\eta)$ where $\eta > (1-\beta)/(\alpha-\beta)$, then[3]

$$C = (1-s)Y \qquad N^C = \frac{1-s}{1-\beta}N \qquad K_1^C = \frac{1-s}{1-\beta}K_1 \qquad K_2^C = \frac{1-s}{1-\beta}K_2$$

$$\dot{K}_1 = sY \qquad N^1 = \frac{s}{1-\beta}N \qquad K_1^1 = \frac{s}{1-\beta}K_1 \qquad K_2^1 = \frac{s}{1-\beta}K_2$$

$$Q_2\dot{K}_2 = -\beta Y \qquad N^2 = -\frac{\beta}{1-\beta}N \qquad K_1^2 = -\frac{\beta}{1-\beta}K_1 \qquad K_2^2 = -\frac{\beta}{1-\beta}K_2$$

where $s = \beta + (1-\beta)/\eta < \alpha$ and where the distribution of inputs among outputs are made according to (2) and (3). The interpretation is that resource input "contributes" the equivalent of $-N^2 = \frac{\beta}{1-\beta}N$ units of labor. Likewise for K_1 and K_2. Furthermore, $w = (1-\alpha-\beta)Y/N$ and $r = \alpha Y/K_1$. We obtain the SAM of Table 3, which illustrates the basic anomaly. In Section 7 we use this example to illustrate an approach to resolving the anomaly.

4   Non-green accounting

By non-green accounting we mean approaches employed by statistical agencies of the world prior to say 1990. Many agencies still use the non-green approach. There are three sorts of primary factors: labor N, reproducible capital, K_1, and natural resources. Roughly speaking these three inputs are treated the same. In particular there is no modern treatment of the value of depletion of natural resources.

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[3]This follows from the analysis of Asheim, Bucholz, Hartwick, Mitra and Withagen (2007), by setting $A = 1$, $N(0) = 1$, $\varphi = 0$ and $\alpha > a = b > \beta$ and writing $s = a = b$.

Table 4: The social accounting matrix with non-green accounting

	input N	input K_1	input K_2	NNP
output C	$w\tilde{N}^C$	$r\tilde{K}_1^C$	$Q_2 R^C$	C
output $\dot{K}_1$	$w\tilde{N}^1$	$r\tilde{K}_1^1$	$Q_2 R^1$	$\dot{K}_1$
NNI	wN	rK_1	$-Q_2\dot{K}_2$	$C + \dot{K}_1$

To illustrate we consider again the DHSS model, with the feasibility set determined by (4). The intertemporal allocation is the same as before; in particular, it is competitive. However, now resource extraction, $R = -\dot{K}_2$, is treated as input in the national accounting, in line with N and K_1. Hence, the value of resource extraction is not netted out, implying that measured NNP becomes $Y = C + \dot{K}_1$.

Now we can distribute inputs among outputs as follows:

$$\tilde{N}^C = \tfrac{C}{Y}N \qquad\qquad \tilde{K}_1^C = \tfrac{C}{Y}K_1 \qquad\qquad R^C = \tfrac{C}{Y}R$$

$$\tilde{N}^1 = \tfrac{\dot{K}_1}{Y}N \qquad\qquad \tilde{K}_1^1 = \tfrac{\dot{K}_1}{Y}K_1 \qquad\qquad R^1 = \tfrac{\dot{K}_1}{Y}R$$

This yields the SAM shown in Table 4. In this matrix the column sums follow from the distribution of inputs among outputs, and the row sums follow when in addition we invoke the assumptions that the allocation is competitive and the production function F exhibits constant returns to scale.

This account is not incorporating a value to the loss of natural capital (that is, the Hotelling rent is not taken into account) and is in this sense both non-green and somewhat old-fashioned.

5   Renewable resources

Consider now the case where the resource is renewable. In particular, let the feasibility set, $\mathcal{Y}$, be determined by $(C, -\dot{K}_2, K_1, K_2) \geq 0$, $N > 0$ constant and

$$C + \dot{K}_1 \leq F(N, K_1, R) \tag{5}$$

$$R + \dot{K}_2 \leq \gamma K_2 , \tag{6}$$

where F is a quasi-concave and constant-returns-to-scale production function and $\gamma \geq 0$. The linear regeneration function γK_2 ensures that $\mathcal{Y}$ is cone, so that we have constant returns to scale for the whole system. Note that if $\gamma = 0$, then we are back to the DHSS model. In this model where the resource is renewable,

Table 5: The social accounting matrix with a renewable resource

	input N	input K_1	input K_2	NNP
output C	wN^C	rK_1^C	$\gamma Q_2 K_2^C$	C
output $\dot{K}_1$	wN^1	rK_1^1	$\gamma Q_2 K_2^1$	$\dot{K}_1$
output $\dot{K}_2$	wN^2	rK_1^2	$\gamma Q_2 K_2^2$	$Q_2 \dot{K}_2$
NNI	wN	rK_1	$\gamma Q_2 K_2$	$C + \dot{K}_1 + Q_2 \dot{K}_2$

(i) Q_1 is constant and equal to 1, so that $rQ_1 - \dot{Q}_1 = r$, and

(ii) $rQ_2 = \gamma Q_2 + \dot{Q}_2$ by the no-arbitrage equation, so that $rQ_2 - \dot{Q}_2 = \gamma Q_2$.

In this case the SAM becomes the one shown in Table 5, where the distribution of inputs among outputs is made according to (2) and (3). This immediately yields the column sums in the table, while the row sums follow when in addition we invoke the assumptions that the allocation is competitive and the production function F exhibits constant returns to scale. To see this, note that by using (6) we get

$$C + \dot{K}_1 = wL + rK_1 + Q_2 R = wL + rK_1 + \gamma Q_2 K_2 - Q_2 \dot{K}_2 \,.$$

The basic anomaly still remains: Greening the NNP in an appropriate way leads to an entry of zero for the value of the current quantity of fish being used, net of renewal of the stock, on the national income side of the national accounts.

6 Durable exhaustible resources

Copper, gold, platinum, etc. are examples of durable exhaustible resources. Current extraction diminishes the stock K_3 in the ground but now the extraction gets added to a stock K_2 in use above ground. Earlier extraction remains in use, while the current extraction gets added to material being used above ground. An in-ground stock is depleted while an above-ground stock is added to each period.

We assume that the production of the composite consumer-investment good and extraction activity each use our durable resource as an input. In particular, let the feasibility set, $\mathcal{Y}$, be determined by $(C, -\dot{K}_3, K_3) \geq 0$, $N > 0$ constant,

$$C + \dot{K}_1 \leq F(N_F, K_{1F}, K_{2F})$$
$$\dot{K}_2 = -\dot{K}_3 \leq G(N_G, K_{1G}, K_{2G}) \,,$$

Table 6: The social accounting matrix with a durable exhaustible resource

	input N	input K_1	input K_2	input K_3	NNP
output C	wN^C	rK_1^C	$(rQ_2 - \dot{Q}_2)K_2^C$	0	C
output $\dot{K}_1$	wN^1	rK_1^1	$(rQ_2 - \dot{Q}_2)K_2^1$	0	$Q_1\dot{K}_1$
output $\dot{K}_2$	wN^2	rK_1^2	$(rQ_2 - \dot{Q}_2)K_2^2$	0	$Q_2\dot{K}_2$
output $\dot{K}_3$	wN^3	rK_1^3	$(rQ_2 - \dot{Q}_2)K_2^3$	0	$Q_3\dot{K}_3$
NNI	wN	rK_1	$(rQ_2 - \dot{Q}_2)K_2$	0	$C + Q_1\dot{K}_1+$ $(Q_2 - Q_3)\dot{K}_2$

$N_F + N_G = N$, $K_{1F} + K_{1G} = K_1$, and $K_{2F} + K_{2G} = K_2$, where F and G are quasi-concave and constant-returns-to-scale production functions, with all inputs constrained to be non-negative. Then (i) Q_1 is constant and equal to 1, so that $rQ_1 - \dot{Q}_1 = r$, and (ii) Q_3 increases with the rate of interest by Hotelling's rule, so that $rQ_3 - \dot{Q}_3 = 0$, since K_3 is a non-renewable and exhaustible resource. In the absence of decay in a unit above ground (no rusting) the above-ground price Q_2 is simply the present value of future rentals. The difference $Q_2 - Q_3$ is the minimized extraction costs of the resource.

In this case the SAM becomes the one shown in Table 6, where the distribution of inputs among outputs are made according to (2) and (3). This implies the column sums in the table, while the row sums follow when in addition we invoke the assumptions that the allocation is competitive and the functions F and G exhibit constant returns to scale. This account in Table 6 is free of anomalies for the above-ground stock K_2, while the anomaly for the in-ground stock K_3 remains the same.

7   A resolution

Weitzman (1976) investigated the meaning of NNP within a full intertemporal model of an economy. The question provoking Weitzman was: does a rise in NNP across periods mean that some identifiable concept of national welfare has risen? To get an answer, he analyzed a change in NNP in a framework that has within it, some standard measure of national welfare. A standard welfare measure is the present value of the stream of utilities of consumption into the indefinite future. The future stream of utilities depends on among other things the savings behavior postulated

as well as on the nature of the technology of production and the endowments of the economy. In Weitzman's (1976) analysis, NNP becomes proportional to a present value concept that can be interpreted as a welfare-related entity.

Subsequent works on "the Weitzman question" include the contributions of Pemberton and Ulph (2001), Asheim and Weitzman (2001), Li and Löfgren (2006), Sefton and Weale (2006) and Asheim and Wei (2009). The model or models employed by these contributors should of course have an NNP and a corresponding value of inputs for an instant of time in them. We proceed now to draw on the Sefton-Weale accounting methodology (national income is the present value of the future interest on consumption) and its use by Asheim and Wei (2009) (sectoral income is the present value of the future interest on cash-flow accruing to the sector) and carry out our analysis within the Cobb-Douglas version of the DHSS model with corresponding SAM in Table 3. We show that this provides a resolution to our anomaly.

If $(X(t))_{t=0}^{\infty}$ is the cash-flow accruing to a sector, then the sector's income as the present value of the future interest on its cash-flow is given by the following formula:

$$\int_0^\infty r(t)p(t)X(t)dt\,,$$

where, as before, $r(t)$ is the real interest rate at time t and $p(t)$ is the present value price of consumption at time t, being a factor used to discount values at that time back to time 0. However, instead of making use of this formula, in the simple case illustrated in Table 3 we can disaggregate the income side of the national accounts by means of the following arguments.

The total "cash-flow" of the economy equals consumption. However, since aggregate income is NNI $= (1 - \beta)Y$ and consumption C equals $(1 - s)Y$, consumption must be multiplied by $(1 - \beta)/(1 - s)$ to arrive at income. The reason is that consumption is increasing, so that current NNI, being the present value of future interest on consumption, is greater than current consumption. Likewise, current cash-flow to labor (= their wage income, $wL = (1 - \alpha - \beta)Y$) must be multiplied by $(1 - \beta)/(1 - s)$ to arrive at income accruing to workers. Moreover, current cash-flow to capital (= $rK_1 - \dot{K}_1 = (\alpha - s)Y$) must be multiplied by $(1 - \beta)/(1 - s)$ to arrive at income accruing to capital owners. Finally, current cash-flow to the suppliers of extracted resource (= $-Q_2\dot{K}_2 = \beta Y$) must be multiplied by $(1 - \beta)/(1 - s)$ to arrive at income accruing to resource owners.

By distributing inputs among outputs according to (2) and (3) we then obtain the SAM illustrated in Table 7. The anomaly that natural capital makes no appearance

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Table 7: The social accounting matrix based on the theory of national accounting

	input N	input K_1	input K_2	NNP
output C	$\frac{1-\alpha-\beta}{1-s}C$	$\frac{\alpha-s}{1-s}C$	$\frac{\beta}{1-s}C$	C
output $\dot{K}_1$	$\frac{1-\alpha-\beta}{1-s}\dot{K}_1$	$\frac{\alpha-s}{1-s}\dot{K}_1$	$\frac{\beta}{1-s}\dot{K}_1$	$\dot{K}_1$
output $\dot{K}_2$	$\frac{1-\alpha-\beta}{1-s}Q_2\dot{K}_2$	$\frac{\alpha-s}{1-s}Q_2\dot{K}_2$	$\frac{\beta}{1-s}Q_2\dot{K}_2$	$Q_2\dot{K}_2$
NNI	$\frac{(1-\alpha-\beta)(1-\beta)}{1-s}Y$	$\frac{(\alpha-s)(1-\beta)}{1-s}Y$	$\frac{\beta(1-\beta)}{1-s}Y$	$(1-\beta)Y$

in the national income row does not arise. However, there is the new anomaly: the entry for reproducible capital, $(\alpha-s)(1-\beta)Y/(1-s)$, is smaller than the total value of its net productivity, αY. This new anomaly appears also for a simple economy without natural capital and is thus somewhat distinct from accounting anomalies associated with greening *per se*. It is fair to say that national accounts that are based on modern theory of national accounting will be quite different from the accounts done with traditional methods, whether the latter account correctly for greening or not. Entries in the account in Table 3 contain no savings rate s, whereas those in Table 7 do contain the current savings rate s. The new anomaly associated with NNI in Table 7 remains of interest here because, like our "green accounting anomaly", it stands out when the accounts are carried out with the SAM framework.

This resolution of the original anomaly (and the occurrence of the new) is tied to the observation that, even though the technology is stationary, the environments for the workers, the capital owners, and the resource owners are not stationary. In our example, the workers experience an increasing wage, the capital owners a decreasing interest rate, and resource owners an increasing resource price. Thus, "terms-of-trade" improve for workers and in particular for resource owners, while they deteriorate for capital owners. If taking this into account when calculating the functional shares—as we have done in Table 7—the accounting anomaly, indicating that the exhaustible resource does not contribute productively, vanishes.

8   Concluding remarks

The central paradox we have set out for green national accounting is that procedures that seem appropriate on the product side of the accounts, namely adding disinvestment terms for natural capital being used up in the current period, have somewhat

anomalous implications for the income side of the national accounts. For the case of oil (a non-durable, non-renewable natural resource) and fish (a non-durable, renewable natural resource) we see that greening on the product side of the accounts, using the traditional methodology, leads to the disappearance of oil or fish as an income term on the income side of the national accounts (net of natural regeneration). Our natural resources become somewhat intermediate in the sense that their value as inputs get embodied in consumption and investment goods produced but fail to show up as values for aggregate income. Inputs that we should consider primary fail to be appearing as part of national income, in contrast with inputs such as reproducible capital and labor or even land. The anomaly in question drops out, so to speak, when accounting is done with a social accounting matrix (SAM). The SAM framework forces one to keep track of both output or product values and input or income values simultaneously.

We expanded our purview to national accounting methodology linked the theory of national accounting in the tradition of Weitzman (1976), in particular as developed by Sefton and Weale (2006) and Asheim and Wei (2009). We observed that by following the SAM "discipline", the original anomaly was resolved and a new one appeared, in the sense that reproducible capital on the income side of the accounts differed from those familiar when the accounting methodology was traditional. We argued that this resolution of the original anomaly (and the occurrence of the new) is tied to the observation that, even though the technology is stationary, the environments for workers, capital owners and resource owners are not stationary in an evolving economy substituting reproducible capital for natural capital in order to sustain well-being.

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